Quality Assurance in Fire Safety Engineering

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To my mother and to the memory of my father

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ABSTRACT

This thesis is a study of the theory of quality assurance in fire safety engineering. The aims of the study are to examine the implication of the general concepts of quality and quality assurance in the context of fire safety engineering, to investigate the causes and effects of the development of quality assurance in fire safety engineering firms, and to identify the factors that affect the effectiveness of the quality systems in these firms.

Research were carried out from four major perspectives: (1) quality definition of fire safety systems in buildings, (2) quality assurance in fire safety engineering projects, (3) quality assurance in fire safety engineering firms, (4) the macro quality assurance system in fire protection industry.

A model for defining quality of fire safety systems in buildings is described. Features of quality assurance in fire safety engineering are identified. A systematic approach for assuring quality in fire safety engineering projects is proposed, which consists of total system quality planning, sub-system quality planning, and quality management systems in fire safety engineering firms.

The investigation found that the driving forces for fire safety engineering firms to adopt quality assurance come from client's need, market competition, development of certification schemes, and the business development strategy of the company. Research data suggests that fire safety engineering firms have gained benefits through the implementation of quality assurance. However, the effectiveness of quality systems are affected by a number of factors both internal and external.

Research results also suggest that a distinctive macro quality assurance system exists in the fire protection industry. This macro system has significant influence on the quality of fire safety engineering. Major components of the macro system include the government, insurers, quality certification bodies, building authorities, fire authorities, trade and professional bodies.

It is concluded that the total quality approach to achieve quality assurance in fire safety engineering should be established on the basis of quality planning and organisation of the construction project, quality management in fire safety engineering firms, and the operation of the macro quality assurance system in the industry. Development of a quality culture within the fire protection industry is essential for the achievement of a significant level of quality.

CONTENTS

Chapter 1 Introduction

Fire safety is an ancient subject that evolves with the progress of human civilisation. While mankind learned how to make fire, he made a remarkable step toward civilisation. However, when men first indulged themselves in the light and heat of fire at the cold dark night, they might also have learned that they had to control the fire carefully. An uncontrolled fire could be disastrous. Since then, men have had the awareness of fire safety.

Records of human efforts to control fire can be found throughout the history. However, unwanted fires continue to devour human lives and property. Statistics shows that accidental fire in buildings claimed 667 lives in the UK in 1991 (ANON, 1993). The battle between men and fire continues.

With the modern sophistication of built environment, fire protection becomes even more important than ever. Advanced engineering concepts and techniques are brought in to the ancient subject of fire safety. Fire safety engineering comes into existence.

Quality is also an old subject that has been developed since ancient civilisation. Archaeological findings and the remains of ancient structures indicate that by the time of the construction of Egyptian pyramids, conscious efforts of pursuing quality had emerged (Banks, 1989). As the industrialisation resulted in the great improvement of well-being of the mankind, the endeavour to enrich quality of life has reached its highest level. Recent decades saw an enlightenment of quality awareness in the industrial world. Striving for a better understanding of the concept of quality and for improved methods of quality control, many industrial practitioners as well as academic researchers devoted great efforts to the development of the theories and practices of quality management. The ancient subject of quality has become a hotted topic in current management research.

This thesis joins the two ancient subjects of fire safety and quality together, and attempts to examine their new relationship which is enhanced by the advance of modern science and technology.

While manufactured equipment and engineering techniques are brought into buildings for the purpose of fire protection, an unstated assumption is that such equipment and techniques will function as effectively as they are expected to when a fire occurs. That is to say, quality of fire safety engineering is an intrinsic concept of fire safety.

Modern theories and methods of quality management arose from the industrialisation in the late nineteenth and early twentieth centuries, and developed rapidly during and after the Second World War. Among those effective theories and methods of quality management was quality assurance.

Quality assurance was developed originally from manufacturing activities to meet the need for controlling quality of supplied products. The establishment of third-party quality certification, especially the quality accreditation and quality certification systems in many countries, enabled the wider application of the philosophy and methods of quality assurance in various industrial areas. In early 1980s, quality assurance was introduced into construction practice in the UK.

Because of its origin in manufacturing industry, the theory and method of quality assurance need to be examined in the context of construction industry and to be modified to agree with the features of construction practice. A number of research project have been carried out for such purposes. While some of these projects overlook the matter of quality assurance from the whole construction industry point of view (Atkinson, 1987; Ashford, 1989; Duncan et al, 1990; CIRIA, 1990a), others examine the issue from different perspectives such as building (Griffith, 1990), building services engineering (Foster, 1986; Gregory, 1989), concrete products (Gunning, 1987), architectural practice (RIBA, 1990), surveying (RICS, 1989) and contractual processes (CIRIA, 1990b).

In the fire safety engineering sector of the construction industry, quality assurance has been introduced into practice for years. With the recent development of the specialised industrial quality certification schemes by the British Standards Institution (BSI) and the Loss Prevention Certification Board (LPCB), many fire safety engineering firms have established the quality systems in accordance to BS5750/ISO9000. However, there has been no systematic research which examines the theoretical issues in relation to quality assurance in fire safety engineering, such as how the concept of quality should be defined in fire safety engineering, how the existing quality assurance methods should be modified to meet the special need of fire safety engineering, what are the causes and effects of quality assurance in the fire safety engineering firms, and what are the factors that affect the effectiveness of quality assurance in these firms.

With the attempt to examine the theory of quality assurance in the context of fire safety engineering, the aims of this thesis are therefore defined as:

• To define the concept of quality in the context of fire safety engineering, with special reference to fire safety systems in buildings;

• To identify special features and characteristics of fire safety engineering that are concerned with quality assurance, and to explore the implication of the philosophy and methodology of quality assurance in the area of fire safety engineering;

• To investigate the causes and effects of quality assurance in fire safety engineering firms, and to identify the factors which affect the development and implementation of the quality systems in these firms.

To fulfil these aims, research has been carried out on four perspectives which construct a systematic approach for the investigation. These perspectives are:

(1). The conceptual perspective, which examines the definition of quality in fire safety engineering, and investigated the features and characteristics of quality assurance in fire protection industry in general;

(2). The project perspective, which examines the application of quality assurance in fire safety engineering projects in buildings;

(3). The company perspective, which investigate the causes and effects of quality assurance in fire safety engineering firms, and the process of organisational change in these firms that is brought about by the introduction of quality assurance;

(4). The macro system perspective, which studies the environmental settings and the macro quality assurance system in the fire protection industry.

An attempt has been made to explore the human aspect of quality assurance which is the prominent topic of current research in quality assurance. While research work was carried out to examine the practice of quality assurance in fire safety engineering firms, some investigations were made to examine some human behavioural factors that influence the organisational changes accompanied with the introduction of quality assurance into the companies.

In addition, an attempt has been made also to examine the current difficulties in evaluating the effectiveness of a quality assurance programme in fire safety engineering firms.

Research data were constructed by a series of interviews, sixteen case studies, a questionnaire survey, and secondary data from various documents such as published literature, company profiles, annual reports, and quality manuals.

The outline of the thesis

The main text of the thesis consists of ten chapters. While this chapter is intended to give a brief introductory look at the research background and the thesis, the remaining nine chapters can be grouped into three parts:

Chapters 2, 3, 4, gives a comprehensive review of the literature in the areas which are related to the research. The major theories and research works which provide the knowledge basis and theoretical background for the research are reviewed. The background, purposes and methodology of the research are discussed in detail after the literature review.

Chapters 5 to 9 present the research work, with each chapter presenting the work from a distinct but interrelated perspective.

Chapter 5 defines the concept of quality in the context of fire safety engineering;

Chapter 6 examines the practice of quality assurance of fire safety engineering in building projects, and proposes a systematic framework for quality assurance of fire safety engineering in building projects;

Chapter 7 studies the causes and effects of quality assurance in fire safety engineering companies, and examines the factors that affect the effectiveness of the quality systems in these companies;

Chapter 8 describes the research findings on the macro quality assurance system in the fire protection industry;

Chapter 9 reviews the methods for assessing the effectiveness of quality management programme and discusses the current issues in evaluation of quality assurance programmes in fire safety engineering firms.

In the last chapter of the thesis, Chapter 10, the research findings are concluded and discussed. Topics for future research are recommended.

The main text of the thesis is followed by the appendices which present the sample questions that were used for interviewing, the sample questionnaire that was used for the postal survey, and profiles of fourteen companies in which the case studies were carried out.

Chapter 2 Quality, Quality Management and Quality Assurance

This chapter reviews the concepts and theories of quality, quality management and quality assurance that are relevant to the research work presented in the thesis. The recent development in quality management and quality assurance are reviewed, and the background of the present research is discussed.

2.1 The concept of quality

The word 'quality' is frequently used in our daily life. However, the exact meaning of quality varies with the circumstances in which it is concerned. Sometimes it implies a sense of fineness, luxury, or excellence, while in other situations it can mean 'satisfaction of expectation', or 'value for money'. In academic literature the term 'quality' has many definitions as it is applied to a very broad range of items, topics and concepts.

Crosby (1979) defines quality as 'conformance to requirements or specifications'. He suggests that, in order to manage quality adequately, the attributes of quality should be measurable. His definition emphasises the engineering and manufacturing aspect of quality control, i.e. the consistence and conformance of products. A quality product is one with all the attributes and characteristics conforming to the predetermined specification. The philosophy of the quality control is to simplify engineering and production control and therefore to reduce the cost of mass production control. A weak point of this definition, however, is that it does not reveal the link between conformance with specification and consumer's expectation of product quality.

Another commonly used definition of quality is 'Quality is fitness for purpose or use'. (Juran, 1979) This definition places emphasis on the functions of products, including 'quality of conformance' as well as 'quality of design'. The requirement of consumers has been concerned in product design and specifications. Ishikawa (1985) further stresses the importance of consumer's requirement. He suggests that 'the first step in quality control is to know the requirement of consumers'. His definition of quality control is:

> 'To practice quality control is to develop, design, produce, and service a quality product which is most economical, most useful, and always satisfactory to the consumer.' (Ishikawa, 1985)

Other widely used definitions of 'quality' include:

> 'Quality is the total composite product and service characteristics of marketing, engineering, manufacture, and maintenance through which the product and service in use will meet the expectation of the customer.' (Feigenbaum, 1983)

> 'Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.' (BSI, 1987a)

Some researchers, for example, Parasurman et al (1985), find that quality is an elusive and indistinct construct, often mistaken for imprecise adjectives such as 'goodness', or 'luxury', or 'shininess', etc. They suggest that few academic researchers have attempted to identify and model quality because of the difficulties involved in isolating and measuring the construct.

Garvin (1988) has summarised five existing approaches to defining quality. They are the transcendent approach, the product-based approach, the user-based approach, the manufacturing-based approach, and the value-based approach. After discussing the advantages and disadvantages of each approach, he argues that the coexistence of these different approaches has several important implications: (1) It helps to explain the existence of the often competing views of quality held by members of the marketing, engineering, and manufacturing departments. For example, marketing people who are involved in the field and have frequent contacts with customers would refer to take an user-based approach which interprets quality as 'to meet customer's requirements', while manufacturing people who are primarily concerned about 'conformance of products to the specification' are more likely to take the manufacturing-based approach. (2) The conflicts of these competing views can cause serious breakdowns in communication between different departments. (3) Open acknowledgement of the coexistence of competing views and flexible employment of such multiple perspectives can bring benefits to companies. Summarising the views of Grant and Bell (1961), Hagan (1984), Heany and Vinson (1984), Ishikawa (1984a) and Paterson (1962), Garvin (1988) suggests that '...companies are likely to suffer fewer problems if they employ multiple perspectives on quality, actively shifting the approach they take as products move from design to market'.

Garvin (1988) argues that the concept of quality can be defined in a disaggregating way. He proposes that the following dimensions of quality can be identified as a framework for analysis:

- Performance
- Features
- Reliability

- Conformance
- Durability
- Serviceability
- Aesthetics
- Perceived quality

Having reviewed the various approaches of defining quality, it is important to note the following points:

(1). Judgement of 'good quality' or 'poor quality' is rather a matter of subjectivity, which can be influenced by individual's preference and habit. When purchasing a new item, some consumers may prefer ones with high reliability and long duration but give little consideration to its appearance. Other consumers may regard the appearance of an item as an important quality feature and choose ones which look good.

The understanding of the word 'quality' is also influenced by the circumstance in which the interpretation is made. In different circumstances quality often has different implication. For example, in a manufacturing workshop and in the market, operators of manufacturing line and consumers of the final products would possibly understand the word 'quality' in different ways.

Therefore, differences among definitions of the concept 'quality' and their implications are inevitable. Implications of quality vary in circumstances and with the people involved.

However, to make quality manageable, the meaning of quality should be clearly defined when a specified product or service is involved.

(2). Quality of a product or service can be defined and interpreted along two dimensions. One dimension is 'the delivering process' through which the product or service is delivered, such as design, manufacturing, installation, commissioning and maintenance. The other dimension is the attributes of the product or service, involving all features and characteristics that the product or service has in order to 'satisfy stated or implied needs' (BSI, 1987a). These features and characteristics can be analysed and specified in sub-dimensions such as performance (or function), reliability, durability, maintainability, aesthetics, and so on.

(3). From a supplier's standpoint, the purpose of quality management is to deliver products or services which provide consumers with maximum satisfaction. To achieve this purpose the supplier should have a good understanding of the consumer's requirements for the product or service. It is the first and possibly the most difficult task that a supplies has to undertake when a new product or service is developed. As consumer's requirements can be subject to individual's habits and preference, specification of quality attributes should defined on the base of popular requirement which represents the needs of most consumers.

(4). To some particular kinds of products and service, requirements may not only come from consumers but also come from other interest groups. Therefore, some special requirements of which the consumer may not be aware of or concerned about should also be taken into considerations. For example, the requirements for environment and safety. The requirements for a fire protection product should always be considered with the adequate protection to life and property as the first need to be met.

(5). The conformance to specification is the measurement of quality. Specifications are the base upon which quality is measured and managed. Once the specification is set, quality is to conform to the specification. While quality characteristics of a product or service is specified, it should be made as measurable as possible. One of the problems remains in quality management research and practice is that in some circumstance it is difficult to measure some subjective dimensions of quality characteristics, such as taste of foods and the aesthetic requirement of a building.

2.2 Evolution of quality management

Evolution of modern techniques for quality control and quality management occurred in several basic stages. A number of authors have divided these stages in different ways.

Feigenbaum (1983) identifies these stages as 'operator quality control', 'foreman quality control', 'inspection quality control', 'statistical quality control', 'total quality control' and 'organisation-wide total quality management'.

Garvin(1988) divides the evolution of quality movement into four 'quality eras': inspection quality control, statistical quality control, quality assurance, and strategic quality management.

Other authors such as Abbott and Leaman (1982), Dorsky (1984), Reddy (1980), use only two categories to summarise the characteristics of the evolution of quality concepts: quality control and quality assurance.

Banks (1989) argues that a more detailed review of the evolution of quality control requires that these developments be considered in smaller time frame. He gives a chronological review on the history of quality control and quality management.

It is the purpose of this part of the thesis to review the knowledge of quality management. It presents a brief description of the historical development of the subject, which is followed by detailed review of the evolution of the concepts, theories and techniques of each quality movement.

2.2.1 A Brief Review of History

Human effort to control and improve quality can be traced back to as early as ancient Egyptians and other ancient civilisations (Banks, 1989). Halpern (1978) suggests that the perfection of the pyramids, the flawlessness of the classical Greek master works, and the endurance of Roman structures attest to a conscious effort to control quality.

However, before the industrialisation, manufacturing activities remained in small scales and were carried out by individual craftsmen or small workshops. Craftsmen and workers were responsible for inspection of their own work. Quality of the work relied on the skill and competence of the craftsmen and workers.

The industrialisation in the late 19th and early 20th centuries saw the rapid development of mass-manufacturing production. Needs for efficient ways to organise large scale production lead to the birth of scientific management, known as Taylorism, which promoted the specialisation of jobs and work supervision. Taylor (1919) singled out quality inspection as an assigned task for one of the eight 'functional bosses' (foremen) that were required for effective shop management. Radford (1922) promoted the function of quality inspection one step further by arguing that quality inspection should be viewed as a distinct management responsibility. Inspection departments were for the first time established as a separate management function. But quality control, at that point, was limited to inspection and to such narrow activities as counting, grading, and repairing (Bicking, 1958).

A remarkable breakthrough in the history of quality control and quality management was the research work by scientists in the Quality Assurance Department in Bell Telephone Laboratories in late 1920s, who were late engaged in the War Department of the United States during the war (Wadsworth, et al, 1986). In 1925, Walter A. Shewhart (1931) published his invention of the control chart. In the same year, Harold F. Dodge produced the basic concepts of sampling inspection by attributes(Wilks, 1962). Their work laid the foundation of the modern discipline of statistical quality control.

The Second World War accelerated the development and spread of statistical quality control. This is mainly because of the military requirement to ensure the quality of weapons and components that were produced in large quantities by multiple suppliers. With the involvement of statisticians from Bell Laboratory, a system of acceptance sampling procedures was developed to be used by quality inspectors from military purchasers. After years of refinement and revision, these techniques resulted in the famous US Military Standard 105 (MIL-STD-105). (Dodge, 1969c) Meanwhile, the knowledge of quality control was disseminated throughout the United States by means of various training programmes on statistical quality control as well as the publication of the journal Industrial Quality Control. (Banks, 1989)

From early 1950s, the theory and practice of quality management have been developed dramatically. Shortly after the war, quality control was introduced from the United States to Japan, by Dr. W. E. Deming, Dr. J. M. Juran and other American quality experts (Ishikawa, 1985). This led to a series of development in the practice as well as theories of quality management in Japan, which Ishikawa (1985) called it 'a thought revolution in management'. Many new concepts, theories and methods of quality management have been developed both in Europe and in Japan since then. These include quality costs, zero defects, quality circles, quality engineering, total quality control, quality systems, total quality management and quality assurance. These concepts and theories are reviewed in the following section.

2.2.2 Major Concepts and Theories in Quality Management

This section is to give a relatively detailed review on the major concepts and theories in modern quality control and quality management which are employed by business organisations all over the world.

(1). Statistical Quality Control

Statistical quality control involves two major concepts: statistical process control and acceptance sampling.

Statistical Process control (SPC): Shewhart (1931) recognised that variation is an inevitable fact of industrial life. No two parts could be made exactly the same, just as no two leaves from a tree would be precisely alike. Therefore, the problem of quality control is not to eliminate variations, but, to distinguish acceptable variations from fluctuations that indicate trouble. Shewhart suggests that we may predict the way that a phenomenon varies in the future by using of past experience that can be described by statistics. He then develops statistical methods for determining control limits according to the requirements for the product and the capability of the production process. Variations are expected to be within the range of control limits. When variations fall out of the limits, the process is in a probability of out of control. He invented the first control chart to describe and monitor production processes.

Based on Shewhart's discovery, a number of process control charts, together with other statistical techniques, were developed to control manufacturing processes under various circumstances and requirements (Grant and Leavenworth, 1980). Statistical process control is now one of the most powerful tools used by quality professionals.

Acceptance Sampling: A widely used definition of acceptance sampling is 'sampling inspection in which decisions are made to accept or not accept the product or service; also, the methodology that deals with procedures by which decisions to accept or not accept are based on the results of the inspection of samples' (BSI, 1987a).

Sampling techniques are developed on the simple premise that 100% inspection is an inefficient way of sorting good products from bad. An efficient alternative is to check a limited number of items in a production lot, and then to decide on the inspection result of the sample whether the entire lot is acceptable. However, because samples are never fully representative, certain risks exist: One may occasionally accept a production lot that in reality contains a large number of defective items, or may reject a production lot that is actually acceptable. Between 1925 and 1926, Harold F. Dodge and his colleagues in Bell Telephone Laboratories recognised these problems and developed sampling plans that ensured that, for a given level of defects, the risk of accepting an unsatisfactory lot would be limited to a certain percentage (Dodge and Roming, 1959). During and after

Second World War, new concepts and sampling plans, including rules for inspections, were developed and refined. The US Military Standard 105D (MIL-STD-105D) was resulted from these work. (Dodge, 1969a, 1969b, 1969c)

Modern statistical quality control also involves techniques for design and experimentation, reliability analysis, process capability analysis, as well as quality improvement. There are many excellent books on statistical quality control and related subjects, for example, Grant and Leavenworth (1980), Wadsworth et al (1986), Oakland (1989), Banks (1989) and John (1990).

(2). Quality Costs

The theory of quality costs is first developed by J. M. Juran (Garvin, 1988). By early 1950s statistical tools for quality control had been widely used in manufacturing management. However, methods were not available for evaluating the costs and benefits of such statistical techniques in financial terms. 'The cost of the quality function were widely scattered through various accounts in the company's books. Some of these costs were clearly defined and quantifies; others not. (Juran, 1979)'

Juran (1951) first identified that the costs of quality can be categorised into avoidable costs and unavoidable costs. Unavoidable costs are those necessary costs for defect prevention and problem finding-solving, such as the costs of quality planning, new product review, training, process control and necessary inspection. Avoidable costs are costs of failures and unnecessary inspection. He suggests that the avoidable costs, which he analogises it to 'Gold in the Mine', can be largely reduced and eventually eliminated by prevention from the occurrence of failure. Therefore, he argues, quality control is not costly but profitable.

Based on the principles discovered by Juran, Feigenbaum (1983) classifies the costs of quality into two different categories: costs of control and costs of failure of control. Wadsworth et al (1986) further divides them into preventive costs, appraisal costs, internal costs and external costs.

The theory of Quality Costs had a significant impact on people's attitudes on quality control, because it revealed the fact that quality control was not costly but profitable if defects can be eliminated through prevention. This led managers to start rethink their approach to quality control. The defect-prevention approach of quality management then emerged.

However, in practice, the application of the methods of quality costs has come across some problems. In a research report examining the usage of such methods in British manufacturing industry, Dale and Plunkett (1985) highlight the difficulties and inconsistencies found in categorising quality costs. They conclude that quality costs are not needed sufficiently in industry and a clear view of their uses and the advantages of their collection are not wide spread.

(3). Zero Defects

According to Oakland (1989), the concept of zero defects was developed by P. Crosby in the early 1960 while he was in charge of quality for various missile projects. Because of the extreme risk and high cost of the missile projects, the goal of quality control was to completely eliminate defective components. In December 1961 the Martin Marietta Corporation, after years of research, was finally able to deliver a missile with zero defects

(Halpin, 1966) and the term 'zero defects' was coined (Banks, 1989).

The theory of 'zero defects' assumes that defects are caused primarily by three situations: lack of knowledge, lack of proper facilities and lack of attention. While employees can be trained for better knowledge of work and the best possible tools can be provide for use, the attention of employees on their work is vital to quality of the work. If the employee does not care whether or not he makes a mistake, he will probably err. The objective of the Zero Defects Programme is to promote motivation of workers and to arouse 'a constant conscious desire to do any job right the first time'. (Halpin, 1966) An efficient way to achieve this objective is to change employee's attitudes to work. To develop a positive work attitude, all employees are encouraged to participate in quality activities and are assigned the responsibility for building quality into the products during the process, instead of inspecting quality in the final stage (Crosby, 1979).

Another theory of zero defects is developed on the premise that since every defect represents an inadmissible deviation from the limits of specifications, it should be possible to achieve a quality target of zero defects (Gaster, 1978). In other words, since a wide range of variations causes the production of defective units, the tolerance range should be reduced so that all products may meet the specification. Japanese manufacturers has applied the idea with a great success that Karatsu (1984) praises it as an effective way of quality control that makes inspection unnecessary.

A major contribution of zero defects to the thoughts of quality management is that it emphasises worker's motivation and encourages the involvement of employees in quality improvement. It inspired the new thoughts in 'human factors' of quality management. Success experience of some Zero Defects Programme demonstrated the possibility of delivering defect-free products and encouraged manufacturers seeking for the achievement of higher level of quality and greater customer satisfaction.

(4). Quality Circles

The concept of quality circles was developed in Japan in early 1960s. With the rapid growth of industrial techniques, Japanese manufacturers strongly felt the need for a more thorough education of the supervisors, who were the liaisons between management and workers. In some companies, supervisors were already getting together with workers to conduct a series of quality control discussions at the workshop level. All these activities finally culminated in the Union of Japanese Scientists and Engineers (JUSE) publishing the magazine 'QC for Foremen' in 1962. (Banks, 1989) Since then, Quality Circles has been widely spread in Japan. By the year of 1974, the number of Quality Circles registered at the Quality Circles Headquarters in Tokyo was reached nearly 60,000 (Hutchins, 1984).

A Quality Circle is a group of production workers led by a foreman at its nucleus meeting regularly to define, select and solve quality problems. Its role on encouraging employees to participate in and contribute to quality management has been so successful in Japan that Ishikawa (1985) argues that 'where there are no Quality Circles activities, there can be no Total Quality Control activities'.

The idea of Quality Circles was introduced into the West in middle 1970s, initially in the United States. It has been given various names such as Industrial Democracy, Work Place Democracy, Employee Participation Groups (or Circles), Participative Quality Control, QC Groups, Inner Consultations, People Implementing Procedures and Savings (PIPS) and Success Through Everybody's Participation (STEP) (Wadsworth et al, 1986). Many authors, such as Beardsley and Dear (1977), Ingle (1982), Patchin (1983), Robson (1982), and Hutchins (1990), have written books to describe the organisation and operation of quality circles activities. There are successful and unsuccessful stories of such activities in Western companies, which aroused arguments on whether the failing of Quality Circles in some western companies were linked with western culture (Brannan, 1989; Lees and Dale, 1990). However, the success of Quality Circles in Japanese manufacturing companies confirms the positive effects of employee's participation on quality improvement. This eventually leads to the development of a 'company-wide quality control', the Japanese way of total quality management which emphasises the involvement of all members of the company in management of quality.

(5). From Total Quality Control to Total Quality Management

The limit of statistical quality control on managing product quality and the need for a broader control over all areas related to quality were recognised as early as 1950s. Feigenbaum (1956) first proposed the thought of 'Total Quality Control', arguing that quality control must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied. He initially identified three major areas which activities need to be controlled: new product design, incoming material, and production. He also addressed the problems of interface between different function departments and the responsibility of top management. The concept of 'quality system' was invented. Another American quality guru Juran (1951) proposed the concepts of 'quality of design', 'quality of specification', and 'quality of conformance'. He recognised the importance of quality planning and training.

However, the early thought of total quality control remained its concentration on the 'classic' functions of management such as plan, control, and analysis. As the 'human factors' were brought into the theme of management in late 1950s through 1960s, quality specialists became more concerned about human behaviour and its effects on the management of quality. As the results, industry saw the movement of 'zero defects', 'quality circles' and 'company-wide quality control', which had greatly influenced the theory and practice of quality management. And the thoughts of total quality control was eventually expanded and developed into the contemporary theory of total quality management.

Feigenbaum (1983) concludes, in his revised version of 'Total Quality Control', that total quality management should involve three major parts: quality systems, human factors, and tools and techniques. He expands the concept of quality control to cover all the managerial control functions of the organisation and suggests that quality is in its essence a way of managing the organisation.

Oakland (1989) argues that Total Quality Management must starts with understanding quality and is a never-ending process of continuous improvement. He summarises the phases of developing a Total Quality Management programme as 'understanding, commitment and policy, organisation, measurement, planning, design, systems, capability, control, teamwork, training, and implementation'.

Cullen and Hollingum (1987) suggest that total quality management implementation process requires six main steps: (1) understanding, (2) top management commitment, (3) company-wide awareness, (4) planning, (5) implementation, and (6) review. These steps lead to increased understanding and continuous improvement.

Ishikawa (1985) emphasises participation of all divisions and all employees of the company, and a shift of the corporate culture from product orientation to consumer orientation. He has invented the phrase 'the next process is your customer' which inspires the Japanese companies as well as those in other countries to create a new corporate culture of total quality.

Mike (1988) states that, to implement total quality management, a company must have a shared philosophy that outlines the way the company wishes to do things and a core mission that outlines what the company is established to do. He suggests that the following fundamental steps must established before a company starts implementing any total quality management programme: (1). organisation structure; (2) management style; (3). communication; (4) customer orientation; (5) ownership, responsibility of problems, and improvement process.

Quality gurus as Crosby, Conway, Deming, and Juran have also offered their philosophy and teachings on total quality management and quality improvement. Oakland (1989) has made an interesting summary and comparison on these four gurus' approaches. Although these approaches, together with teachings advocated by other quality experts including Oakland himself, vary in their emphasis and in some technical procedures, they all agree with each other in principles.

2.2.3 Recent trends

The theory and practice of quality management has been developing rapidly in recent decades. Total Quality Management is now the theme of contemporary quality management. With the increasing market competition, many businesses now are aware of the importance of quality to business development and, in some cases, to business survival. Quality is becoming an essential business strategy and a core value of corporate culture. As a new subject, total quality management has gained a place in the academic discipline of management. Many university business schools in the UK and the United States tend to include Total Quality Management as a new subject in their curricula.

How to adopt the Total Quality approach into various industrial sectors and business organisations in an effective way is the focus of current quality management research. Achieving Total Quality through corporate culture change has been a new topic of quality management in the past a few years. Many authors point out the importance of culture change to the effectiveness of quality management. For example, Atkinson (1990), Smith (1990), Seddon and Jackson (1990), Davies (1992), Duffin (1992).

A notable trend in recent quality movement is the wide application of quality assurance in the UK as well as in other countries. Quality assurance is an powerful approach to achieve quality and an essential part of contemporary quality management. As the theme of this thesis, it is reviewed in the following sections.

2.3 Quality assurance

The term 'quality assurance' has sometimes been used in confusing ways. For example, it is used by some American and Japanese writers, such as Abbott and Leaman (1982), Garvin (1988), and Ishikawa (1985), to refer to the broadly concept of the 'defects-prevention' approaches to quality management which involve quality costs, zero defects, total quality control, etc. In most circumstances, especially in recent British literature, 'quality assurance' is used as a special terminology that is defined as:

> 'All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.' (BSI, 1987a)

2.3.1 Early development

The phrase 'Quality Assurance' was coined by the quality experts in Bell Telephone Laboratories in 1920s to name their department whose task was to develop the "art and science of inspection engineering" (Wadsworth et al, 1986). Its meaning has changed as the concepts of quality assurance evolved over the past several decades.

During World War II, the Ordnance Department of the Army in the United States was facing the problem of ensuring quality of the large quantities of arms and ammunition from multiple suppliers. To solve the problem, the War Department engaged the quality specialists in Bell Telephone Laboratories. Two solutions were proposed at the time: (1). to give intensive training to the suppliers on the statistical methods of quality control; (2). to develop a system of acceptance sampling procedures to be used by the government. The latter was adopted and the system of acceptance sampling procedures developed. (Dodge, 1969a) This was the earliest idea of supplier's quality assurance.

The work of quality experts in the War Department of the United States was further developed after the war, resulted in a series of standards. The first standard of this kind was US MIL-STD-105A issued in 1950, which was later modified and divided into MIL-STD-105B, MIL-STD-105C, and MIL-STD-105D. (Schilling, 1982; Dodge, 1969c.)

In the United Kingdoms, however, another form of quality assurance had been developed. The British Standards Institution (BSI), an independent and impartial organisation who was founded in 1901 and was granted a Royal Charter in 1929, established the Kitemark scheme for product approval. The early Kitemark scheme was to confirm that samples of the product had been tested by the BSI laboratory against relevant British Standards. Now, the Kitemark scheme for the product certification has included in its requirements the assessment to the producer's capability and quality management systems. This scheme provides the stereotype for third-party quality certification.

2.3.2 Principles of quality assurance

Quality assurance, to quote Juran (1979), 'is the activity of providing, to all concerned, the evidence needed to establish confidence that the quality function is being performed adequately.'

The mechanism of quality assurance is based on the following principle: If evidence shows that a quality management system is established and implemented effectively in accordance with relevant requirements, confidence can be gained that quality of the products delivered under such a system will be constantly maintained at a satisfactory level. Such evidence are obtained from quality audits to the quality management system, i.e. inspection into documents of the system and relevant records which are produced by implementing the system.

The purposes of quality assurance fall in at least one of the following three: (1). To gain customer's confidence on quality of the products so as to obtain market share; (2). To satisfy the requirements from larger purchase organisation(s); (3). As a part of the business development strategy designed by the top management.

Quality assessment can be carried out in three different forms to serve distinct purposes:

A third-party quality assessment is the most common form of quality assessment in current practice, promoted by the development of third-party quality certification. In this type of quality assessment, the supplier's quality management system is audited by an independent organisation who is not involved in either purchase or supply of the products and is credible to both the supplier and the customer.

The next type of quality assessment is the second-party quality assessment in which the quality system is assessed by representatives from the purchase organisation(s). This type of assessment was popular in 1960s and 1970s, and is still used by some large purchaser.

The one-party, or first party, quality assessment is usually conducted on an internal basis. The quality assessment is usually carried out by the quality manager of the supplier's own organisation, or by quality consultants. Results of the assessment are reported internally. This type of quality assessment is usually required by top management or board committee of the supplier to review the status of quality management in the organisation.

In the cases of third-party and second-party quality assessment, a certificate is usually issued after the assessment, which confirms the conformance of the supplier's quality management system to a specified standard. Such practice is recognised as quality certification. And accordingly, the types of quality certification are referred to as third-party certification and second-party certification.

Standards of quality management systems used for quality assessment and certification are specified on the premise that the requirements in the standards are essential measures to be taken for the production of consistent quality. An early example of quality systems standards is the US MIL-Q-9858: Quality Program Requirements. BS5750:1987:Quality Systems is the most widely accepted standard of this kind in current practice (BSI, 1987b).

2.3.3 Recent development in the UK

Early quality management systems were introduced into Britain by the Ministry of Defence for the purpose of quality assurance in their procurement activities. The Quality Assurance Defence Standards MOD-05 series were developed on the basis of US-derived NATO standards. They were eventually adopted as British Standards for the general use of industry as a series of guides to quality assurance. However, these standards were not widely accepted. Various alternatives were developed and used. Quality assurance activities were carried out on a second-party assessment basis while individual purchasers defined their own quality requirements and carried out their own quality assessment. This practice later led to many problems. One of the problem was that a manufacturer would have several customers and each of them insisted on adherence to his own quality requirements and carrying out his own quality assessment. In middle 1970s, it became common for lager manufacturers to have to submit each year to multiple assessment by several major customers. (NEDC, 1977)

The problem was examined in Sir Frederick Warner's report on "Standards and Specifications in the Engineering Industries" (NEDC, 1977). It led directly to an appreciation of the merits of a widely accepted standard for quality management systems that could not only be used by individual purchasers but also by independent third-party certification bodies to assess the capabilities of suppliers (Sherwood, 1990). The British Standard BS5750:1979: Quality Systems was developed under this background. It was subsequently revised in 1987. The new version, which is identical to the International Standards ISO9000 series, has made a great improvement upon the 1979 version and formed the basis of quality management systems and certification schemes in the UK (BSI, 1987b).

A milestone in the development of quality assurance and 'Total Quality' approach in the UK is the National Quality Campaign launched by the Department of Trade and Industry in 1983, following the publication of the 1982 the Government White Paper entitled "Standards, Quality and International Competitiveness" (DTI, 1982). The White Paper sets out the government's policy on its encouragement of increasing the competitiveness of British industry in the field of quality, and of producing in industry a commitment to quality on a total basis. The application of quality systems and Total Quality approach have been rapidly spread throughout the UK. The number of companies registered to various kinds of certification schemes increased from 5335 in 1983 (DTI, 1983) to over 9000 in 1986 (DTI, 1986a). Meanwhile, a national quality certification and accreditation system has been established with the direct involvement from the Government (DTI, 1986b).

The development of quality assurance has drawn increasing attentions from industrial practitioners as well as academic researchers. Discussions on quality and quality assurance are frequently seen and heard in various publications, seminars and conferences. However, much efforts have been focused on the issue of how quality and quality assurance can be developed on the national as well as industrial sectoral bases. For example, Slater (1988), Talwar (1988), Sohal et al (1990), Early (1991), Gaskin (1991), and Hersan (1990). A notable development is the introduction of quality assurance into the building and construction industry, which is reviewed and commented in detail in the following section.

Another topic is the quality systems standard itself. Some authors, for example, Dagnino (1989), Nuland (1990), and Burr (1990), have discussed merits and faults of BS5750/ISO9000 and suggested improvements on the content of the standards. A common view is that BS5750/ISO9000 is too general. While it is applied to a specified product or industry area, supplemental requirements to the quality system related to that product or industry area should be developed.

2.4 Quality assurance in building

Quality assurance has been applied in the sector of construction material and building components of the construction industry for years. Up to middle 1980s, various product approval and quality certification schemes for building material and components were operated in the UK. Some of these schemes have a relatively longer history, while others are newly established, as part of the construction industry's reaction to the National Quality Campaign. Sadgrove (1987) and Ashford (1989) reviewed the quality schemes available in the construction industry to date. However, these schemes were limited in the production and supply of construction material and components. A BRE Survey of quality and value in building shows that 90% cost related error is sourced either design team or in the construction management team (Duncan et al, 1990). The need for better quality and for a broader application of quality assurance in the whole construction industry were highlighted. (CIRIA, 1987; CIRIA, 1988a; Foster, 1986)

It is identified that five sectors in the construction industry where quality assurance may be applied: (1). client, (2). designer, (3). manufacturers, (4). contractors and subcontractors, (5). user. (Gunning, 1987; Griffith, 1990)

Duncan et al (1990) suggest that the problems of unsatisfactory quality in construction are primarily due to the following reasons:

- inadequate training and management of designers, technicians and labour;
- inadequate or incorrect specification at tender;
- inadequate definition of responsibilities within both management groups, namely in the office and on site;
- poor communication between the principal parties in contract;
- inadequate certification routines to ensure that design, materials and workmanship meet specified requirements.

Duncan, et al, (1990) further argue that quality assurance is a good start point to overcome these problems.

However, quality assurance is developed from manufacturing activities. When the principle of quality assurance is applied to the construction industry, modifications are needed.

The NEDC (1985) report, as well as researchers such as Atkinson (1987), Ashford (1989), Griffith (1990), recognise special features of the construction industry and of building activities in regard to the application of quality assurance and quality management. These features can be summarised as following:

(1). The procurement process of a building project is far more complicated than that of production. By tradition, design and construction are separated activities. Design and construction work themselves are usually split again between different practitioners by contracting. The responsibilities of all participants whose work contribute to the quality of the building are complex and, to some extent, difficult to verify.

(2). Almost every building project is 'unique', and so is the construction site. Even when standard design are used, details have frequently to be modified to satisfy the site, regulatory or client requirement. Material and components may have been tested and quality assured, but they are likely to be handled, stored, assembled and installed under adverse site condition.

(3). Statutory authorities regulate design and construction in many ways and stages during the process.

(4). Design and construction staff move from project to project. Employer and co-operation relations change frequently. Each project and each site is likely to have different team members.

(5). Supervision and inspection of construction work are usually not systematic. Inspection procedures are not easy to be clearly regulated. The quality level of individual operative work is unlikely to be clearly defined.

(6). Life cycle of a building project, from inception to completion, may be as long as several years, and also tends to evolve and develop through time.

(7). Some mistakes and defects may remain latent for many years before they show up and cause trouble. Remedial work is likely to be costly and difficult.

(8). Feedback from the building in use to the designer and contractor is usually too late for effective analysis of defective design and construction.

Gunning (1987) points out that the Quality Systems standards BS5750 series, which covers a variety of types of systems for design, manufacture, installation and testing, make no specific reference to the construction process. He argues that these Standards are rather too general for construction, and that a new standard could usefully be produced dealing specifically with the unique problems of construction.

Guidances for applying the quality assurance principles into construction activities are published by professional and research organisations, such as CIOB (1987), CIRIA (1988b, 1990b), CUP (1989), PSA (1988) and RICS (1989). Some books also provide comprehensive and detailed guides on how quality assurance can be developed in the building and construction industry and how quality systems can be used in various types of companies in the industry. (Griffith, 1990; Hughes and Williams, 1991)

Building services, as a prominent sector in the construction industry, has taken an active role in the introduction of quality assurance. It shares with the whole construction industry the need for quality assurance. Apart from the special characteristics shared with the industry, there are three highlighted features which have to be included in development of quality assurance in building services (Scurry, 1983):

(1) All factors that influence operating life of the products and systems must be recognised. Such factors will include handling, storage and installation practices together with operation and maintenance procedures.

(2). Equipment must be designed, manufactured and selected taking account of all the factors that will affect the performance and reliability of the finished products.

(3). Appropriate and adequate quality control procedures must be developed and applied to all phases of the design-installation-maintenance process as a necessary part of quality assurance.

Foster (1985) identifies five areas which should be covered when the quality assurance is applied to building services:

- Design and specification,
- Manufacture,
- Procurement and installation,
- Commissioning and proving,
- Maintenance and monitoring.

He suggests that supplemental requirements to quality systems should be specified accordingly when BS5750 is used in these areas.

Davies (1990) has further discussed in detail on the characteristics and problems of the application of quality assurance in each of these areas.

Fire safety engineering, as it is generally understood, is the application of engineering concepts and techniques for achieving fire safety in a building or any other structure (Malbotra, 1991). As an academic subject, it involves knowledge and techniques derived from a wide range of science and engineering disciplines. Rasbash (1981) identifies 12 areas that comprise fire safety engineering. Marchant (1983) suggests that 46 disciplines and professions hold, or can produce, information which is useful input to fire safety engineering.

As an industry sector, fire safety engineering is in a very special situation. On one hand, it has been recognised as an independent industrial sector within the construction industry. On the other hand, it belongs to the fire protection industry. As it was reviewed in the EDMC report (EDMC, 1990), a simple definition of fire safety engineering seemed not to be available. It seems that the structural context of fire safety engineering within either the construction industry, or the fire protection industry, has not been clearly defined. Nor has the scope and structure of fire protection industry itself. To quote EDMC (1990),

> "The fire industry is clearly diverse and not considered to be homogeneous by people in the various sectors."

This particular situation makes it extremely difficult, in not impossible, to explore the theory and practice of quality assurance from the whole fire protection industry viewpoint.

In building and construction practice, fire safety engineering is segregated into a range of industry branches, with each of these branches trade one or a group of fire protection products and services. From quality assurance viewpoint, fire performance test and approval is one of the oldest form of quality assurance in the construction industry. In recent years various quality certification schemes for fire safety products and services have been launched (for examples, BSI, 1986; BSI, 1988a; LPCB, 1987a; LPCB, 1988; LPCB, 1991). However, these quality certification schemes are developed and implemented separately on the basis of individual operations related to specific products or services. Little has been done to study the theoretical and practical issues of quality assurance from the whole fire safety engineering viewpoint.

Quality certification bodies, such as the British Standards Institution (BSI) and the Loss Prevention Certification Board (LPCB), provide practical guidance and define requirements standards to quality systems for fire safety engineering firms through their Quality Certification Schemes. An increasing number of fire safety engineering firms have adopted quality assurance. However, no scientific research has been done to examine the causes and effects of quality assurance in such firms. Nor has been done to identify the factors that affect the efficiency of quality assurance in these companies.

In a broader context of quality assurance, it is recognised by some researchers that quality assurance is a good start point to implement Total Quality. However, the current practice on quality assurance is focused on establishing a bureaucratic quality system in the organisation. The 'human factors' in quality assurance are to some extent neglected. While human behaviour is just as important as organisational structure and techniques in the context of Total Quality Management, it could be argued that a successful transformation from quality assurance to 'Total Quality' will largely depend on the handling of the 'human factors'. It is therefore necessary to identify such factors and their effects on quality assurance, using scientific research methods. Other aspects which influence the effectiveness of quality assurance also be examined, such as the influence of the business environment.

Chapter 3 Organisation, Organisational Behaviour and Organisational Change

This chapter reviews the concepts and theories of organisation, organisation behaviour and organisation change, which are relevant to the research work that is presented later in the thesis. Particularly, at the end of the chapter, it presents a discussion on the recent trend of applying the theories of organisation behaviour and organisation change into quality management.

3.1 Nature of Organisation

Baron (1986) defines

> "An organisation is any social structure or system consisting of two or more persons who are interdependent and who work together in a co-ordinated manner to attain common goals."

The Scientific Management Movement marked the beginning of the search for systematic and scientific knowledge of organisation and management. Since then the theories of organisation and management have developed rapidly and formed several influential schools.

Organisations are the dominant forms of institutions in our society. Everybody is associated with some organisations in certain ways. Everybody makes his own assumptions on the nature of organisations associated with him and on how these organisations work. These assumptions are the intuitive theory of organisations. Organisation theory as an academic discipline is a body of systematic and scientific knowledge that describes how organisations work and offers suggestions on how they can be constructed and managed to improve their effectiveness and efficiency (Robbins, 1983). Organisation theorists study organisations from different perspectives and under distinct backgrounds. The results of these studies have enabled the formation of several distinct schools of organisation theory. However, the major issues highlighted in organisation study can be summarised as nature and characteristics of organisations, organisation structures, human behaviour in organisations, and organisation change and development.

Classical organisation and management theory, represented by Taylor's scientific management, Fayol's administrative management theory and Weber's bureaucratic model, views organisations as closed systems. It emphasises rationalisation and depersonalisation of behaviour, specification of jobs, clear delineation of authority and responsibility, strict discipline, systems of rules and regulations, and control of organisational process. Classical theorists construct their theories on the premise that the workers are rational economic men, and wish to develop universal principles which are applicable to all organisations. (Kast and Rosenzweig, 1985)

Barnard (1958) is regarded as the first man that proposed the new theory of organisation after traditional organisation theory and the first man who utilised the systems approach in organisation study. He proposed that organisations are co-operative systems. He emphasised the co-operative nature of organisations and stressed the issues of: natural groups within organisations; upward communication; authority from below rather than from above; and leaders who function as the cohesive force.

The Hawthorne Studies (Roethlisberger and Dickson, 1939) is the milestone which initiated the study of human behaviour in organisations and led the development of human relations school of organisation theory. The Studies highlighted the role of informal groups, work restriction norms, the value of decent; humane leadership; and the role of psychological manipulation of employees through counselling. The human relations theorists argue that a business organisation is a social system as well as a technical-economic system. Such a system defines individual roles and establishes norms that may be at variance with those of the formal organisation. The informal work group is a focal unit of consideration. The group has an important role in determining the attitudes and performance of individual workers.

March and Simon (1958), founders of the decision-making school of organisation and management theory, emphasises the importance of decision-making to the work of organisation and management. Simon (1976) argues that because of the cognitive limits on rationality man makes decisions on the basis of satisfaction rather than maximisation or optimisation. That is, man generally seizes on the first acceptable choice, rather than looking for the best choice when he makes a decision. This theory implies that good practice of managing people in organisations is to control the premises on which the decision is made, rather than to give direct orders or to leave them to their own devices. Once the premises are controlled, people can make their own decisions upon the limited alternatives.

The most recent development in organisation and management theory is the contingency approach. Kast and Rosenzweig (1985) offer a contingency view of organisations:

> "The contingency view of organisations and their management suggests that an organisation is a system composed of subsystems and delineated by identifiable boundaries from its environmental suprasystem. The contingency view seeks to understand the interrelationships within and among subsystems as

well as between the organisation and its environment and to define patterns of relationships or configurations of variables. It emphasises the multivariate nature of organisations and attempts to understand how organisations operate under varying conditions and in specific circumstances. Contingency views are ultimately directed toward suggesting organisational design and managerial actions most appropriate for specific situations."

Researchers at the Tavistock Institute of Human Relations have made remarkable contributions to the contingency approach to organisation and management. They suggest that organisations are socio-technical systems with a structure and integration of human activities around various technologies toward the accomplishment of certain goals. (Rice, 1963)

Woodward (1965) found that there were links among technology, organisation structure, and organisation effectiveness. It was argued that there was no one best way in which to organise firms. To achieve a high organisation effectiveness, the structure of the organisation should fit its production technology. The term 'technology' here refers to the processes or methods that transform inputs into outputs in the organisation. Woodward's views were later strengthened by American researchers. Perrow (1967) identified four types of technology: routine, engineering, craft, and nonroutine, and suggested that the more routine the technology, the more highly structured the organisation should be. Bureaucracy appeared to be the best form of organisation for routine operations while temporary work groups, decentralisation, and emphasis on interpersonal processes appeared to work best for non-routine operations.

Burns and Stalker (1961) summarise two basic types of organisation structures: mechanistic and organic.

Mechanistic structures were characterised by high complexity, normalisation, and centralisation. While organic structures were relatively flexible and adaptive. They suggest that organisations with mechanistic structures are effective in a stable, certain environment, and organic structures perform better in a turbulent environment.

Lawrence and Lorsch (1967) argue that there are strong links between the organisation's characteristics and its surrounding environment. Pfeffer and Salancik (1978) point out that to understand the behaviour of an organisation it is necessary to also understand the context within which that behaviour occurred. They suggest that organisations are inescapably bound-up with the conditions of their environmental setting. Consequently, all organisations engage in activities as a direct response to their environment. However, Silverman (1970) provides strong criticism of some theories that treat organisations as if they were living organisms capable of an independent life of their own. Silverman points out that organisations do not react to their environment, but their members do. Weick (1977) argues that the members of an organisation do not respond to the external environment as it actually is, but to their own perception of it. The perceived environment may or may not correspond with 'reality'.

3.2 Organisational Behaviour

A working definition of organisational behaviour given by Baron (1986) is:

> "Organisational behaviour is the field that seeks enhanced knowledge of behaviour in organisational settings through the scientific study of individual, group, and organisational processes, the goal of such

knowledge being the enhancement of both organisational effectiveness and individual well-being."

Organisational behaviour is established as an academic discipline to help us to understand, predict, and influence individual behaviour in organisations. The use of scientific methods in the study of organisational behaviour develops insights beyond "common-sense".

The classical approach to organisation and management placed emphasis on: the work plan; technical requirements of organisation, principles of management; and rational and logical behaviour.

The Hawthorne Studies marked a significant step forward in providing an insight into human behaviour at work, and inspired the development of new management thinking. An immediate impact of the Hawthorne Studies in the development of management thought is the emergence of the human relations school of management theory which makes the most remarkable contribution to the subject of organisational behaviour.

The Hawthorne Studies revealed that people go to work to satisfy a complexity of needs, in contrast to the classical management theory which assumed that people work simply for monetary reward (Roethlisberger and Dickson, 1939). The work of Maslow (1954) strengthened the human relationist's views which emphasise the importance of the wider social needs of individuals and give recognition to the work organisation as a social organisation.

The human relationists recognise the importance of informal organisations. They suggest that informal organisations are always presented one way or another within the formal organisation structure. These informal organisations have significant influence on the motivation of employees who view the organisation through the values and attitudes of their colleagues. Their view of the organisation determines their motivation to work well or otherwise. (McGregor, 1960)

The development of the concepts and theories of organisational behaviour has a significant influence on quality management. Some concepts of organisational behaviour which are very important to the theories and practice of quality management are reviewed below, while Section 3.4 gives further review and comments from the perspective of quality management.

Attitudes

Baron and Byrne (1984) define that 'attitudes are lasting clusters of feelings, beliefs, and behaviour tendencies directed toward specific persons, ideas, objects, or groups in the world around us'. Feelings, beliefs, and behaviour tendencies are three essential components of an attitude. Baron (1986) further explains that 'work-related attitudes' are those toward various aspect of work, work settings, or the people in them. Attitudes often play a key role in shaping behaviour in organisation. People usually act in ways that are consistent with their attitudes. Attitudes also affect some major organisational process such as co-operation and conflict.

Fishbein and Ajzen (1975) suggest that all attitudes are sharpened by information received by the individual, and that new information can be used to reinforce or alter an attitude. Robertson and Cooper (1983) suggest that there are a number of variables which are associated with the direction and degree of attitude change. These include: characteristics of the change agent; form and content of the persuasive communication; and the context within which the persuasive communication is presented.

Commitment

Organisational commitment is represented by the attitudes that is held by individuals toward the entire organisation. It reflects the extent to which an individual identifies with and is involved with his or her organisation (Mowday, 1982). Baron (1986) states that a high degree of organisational commitment is associated with:

(1). strong acceptance of the organisation's goals and values;

(2). willingness to exert effort on its behalf; and

(3). a strong desire to remain within the organisation.

The interest of research into organisational commitment has increased greatly in recent years. However, much of the research have been concerned with the causes of organisational commitment and its effects on work-related behaviour.

Baron (1986) summarises some major factors that affect organisational commitment:

(1). Nature and characteristics of the job. In general, the higher the level of responsibility and autonomy in the job and the more interesting and varied it is then the higher the level of commitment. One the other hand, the greater the tension and ambiguity associated with the job then the lower the level of commitment it produces.

(2). The existence of other employment opportunities. The greater the perceived chances of finding another job and the greater the desirability of such alternatives then the lower an individual's commitment tends to be.

(3). Personal characteristics. Older individuals, especially those with tenure or seniority in their positions and those who are satisfied with their own level of work performance tend to evidence higher levels of commitment than others.

(4). Work environment. For example, the more satisfied individuals are with their supervisors, with the fairness of performance appraisals, and the more they feel their organisation cares about their welfare, the higher their level of commitment.

Research indicates that organisational commitment can affect several aspects of organisational behaviour and organisational effectiveness (Stumpf and Hartman, 1984). These aspects include:

(1). the rates of absenteeism and turnover;

(2). the efforts that individuals are willing to invest and the performance of their work; and

(3). job satisfaction.

The second aspect above is directly relevant to the management of quality. While quality is perceived to be the organisation's goal, the achievement of such a goal relies on the efforts of individuals in the organisation.

Communication

Communication is the process through which one person or group transmits information to another person or group. Davis (1977) identifies six basic steps of a communication process:

- Ideation
- Encoding
- Transmission
- Receiving
- Decoding
- Action

Communication is regarded as the lifeblood of organisations (Hellriegel et al, 1986). Organisations cannot exist without communication. Management is working through others. Managers depend on communication to perform their functions of planning, organising, controlling, etc.

Communication provides the information and understanding necessary for group effort. Communication also provides the attitudes necessary for motivation, co-operation and job satisfaction.

Hellriegel et al (1986) summarise that communication is impeded by three broad types of barriers: physical, personal (social-psychological) and semantic. Physical barriers are environmental factors that prevent or reduce the sending and receiving of communications. They include physical distance, distracting noises and similar interferences. Personal barriers arise from the judgements, emotions and social values of people. They cause a psychological distance between people, which may entirely prevent a communication, filter part of it out or simply cause misinterpretation. Semantic barriers arise from the limitations of the symbolic system itself. Symbols usually have a variety of meanings, and we have to choose one meaning from among many.

Leadership

Leadership is the process of influencing group activities toward the achievement of goals (Bass, 1981). Research into the leadership process prior to the mid-1960s indicated no consistent relationship between leadership style and measures of performance, group processes, and job satisfaction. Some research concluded that the situation within which a leader functions plays a significant role in the determination of the effectiveness of leadership (Hellriegel et al, 1986). However, researchers did little to identify key situational variables.

Contingency approach of leadership research investigated into the variables that permit certain characteristics and behaviours of leaders to be effective in a given situation. Szilagyi and Wallace (1983) suggest that a leader's behaviour can be influenced by the following four factors:

(1). a leader's personal characteristics, including his personality, needs and motives, and past experience;

(2). their subordinates' personal characteristics;

(3). group's characteristics, including group structures, group tasks, and group norms; and

(4). organisational structure characteristics, including hierarchy of authority, and rules and regulations.

Organisational culture

Organisational culture, or 'corporate culture', is the pattern of beliefs and expectations shared by members of the organisation (Schwartz and Davis, 1981).

Deal and Kennedy (1982) identify four key dimensions of organisational culture:

(1). Values. The beliefs that lie at the heart of the organisational culture and are shared by all members of the organisations;

(2). Heroes. The people who embody values by providing role models. They assist in getting values widely accepted and adopted;

(3). Rites and rituals. Routines of interaction that have strong symbolic qualities. Rites and rituals demonstrate to individuals the expectations that the organisation has of them; and

(4). The culture network. The informal communication system or 'hidden hierarchy of power' in the organisation.

Deal and Kennedy (1982) argue that organisational culture is the single most important factor accounting for success or failure of achieving organisational goals. They point out that there are a strong link between strong organisational culture and high performance. Peters and Waterman (1982) further argue that a strong organisational culture is the path to organisation excellence.

Hellriegel et al (1986) summarise four key ideas of the effects of organisational culture:

(1). Organisational culture helps employees, especially newcomers, to understand the company's history and current approach, which in turn, provide guidance about expected behaviour in the future;

(2). It serves to establish commitment to organisational philosophy and values. This provides employees with shared feelings of working toward goals that they believe in;

(3). Organisational culture with its related norms serves as a control mechanism to channel employee's behaviour toward desired and away from undesired patterns; and

(4). Certain kinds of organisational cultures may be related to greater effectiveness and productivity.

Studying organisational culture provides a profound understanding of organisations and organisational behaviour. However, organisational culture is a very new subject in organisation science. There are many to know about it. For example, despite the fact that many writers argue that organisational culture influences organisation performance, there is little 'hard evidence' indicating that a strong culture-performance relationship exists (Hellriegel et al, 1986).

3.3 Organisational Change and Development

Drucker (1980) argues that industry has moved into an age of turbulence, a period of rapid and radical structure shifts. Lippit et al (1985) recognise that a major challenge that organisations are facing is to manage change effectively. Change and development have become the theme of contemporary management.

Goodman and Kurke (1982) define that "Planned organisational change refers to a set of activities and processes designed to change individuals, groups, and organisation structures and processes". Kahn (1974) suggests that to change an organisation means to change the pattern of recurring behaviour of the organisation members.

Smith et al (1982) point out the difficulty of bringing about organisational change: Modern organisations tend to develop sophisticated bureaucracy which rationalises and depersonalises behaviour to make them more predictable and efficient. They are not meant to change.

Hellriegel et al (1986) summarise the major categories of pressures for change:

- Changing technology
- Knowledge explosion
- Rapid product obsolescence
- Changing nature of the work force
- Quality of work life

Smith et al (1982) provide following cues to help understanding and managing changes:

(1). No one likes to change;

(2). When people want to change, it is because they see the new behaviour as being in their own self-interest;

(3). People change most easily when they feel the needs for change;

(4). People change most easily when they have a say in the change;

(5). Resistance to change is a healthy reaction to change;

(6). To view the social settings for change as a whole--not just selected aspects of it.

Lewin (1952) proposes his 'force field analysis' theory to describe how change takes place. He sees change not as an inert, but a dynamic balance of two groups of forces working in opposite directions. These two groups of forces are: the restraining forces against change and the driving forces for change. They form a field of change forces and are in a quasi-stationary equilibrium. Change takes place when the equilibrium is broken and the field is reorganised into a new state which incorporates the intruding new force. (Lippit et al, 1985)

Hellriegel et al (1986) summarise three ways to initiate change:

(1). To increase the strength of the pressures (driving forces) for change;

(2). To reduce the strength of the resisting forces or removing them completely; and

(3). To change the direction of a force--that is, to change a resistance into a driving force for change.

Lewin (1952) describes organisational change as a three phases process: unfreezing, changing, and refreezing. Ottaway (1979) recognises various kind of change agents needed in each phase of the change process. These include change generators, change implementers, and change adopters.

A range of reasons which lead to the resistance to changes in the organisations are recognised and summarised into two categories: (Hellriegel et al, 1986; Organ and Bateman, 1986; Kerr and Kerr, 1972).

(1). Individual resistance to change, which includes

- Selective attention and retention
- Habit
- Dependence
- Fear of the unknown
- Economic reasons
- Security and regression

(2). Organisational Resistance to change, which includes

- Threats to power and influence
- Organisational structure
- Resource limitations
- Sunk cost, or fixed investment
- Inter-organisational agreements

Recent literature on organisational change tend to focus on strategies for change. Achieving organisation excellence through organisational culture change has been a topic that arouses wide interest in organisation and management researchers. Meanwhile, theories of organisational behaviour and organisational change have been applied to other related management subject areas such as quality management and construction management.

3.4 Quality management and its human aspect

Prior to 1960s the approach to quality management was focused on 'inspection' and 'control'. It is usually termed 'quality control', and is featured by its emphasis on the use of statistical methods. The philosophy of quality control based on inspection and control reflects the traditional (or classical) thoughts of management which emphasises planning of work, assignment of responsibility, rational behaviour, and individual performance. The human relations movement, which advocates the exploration of employee's need, work-related attitudes and motivation, communication, and group co-operations, has a great impact on management practice. It also provides inspirations for the development of new approaches to quality management. Zero Defects, Quality Circles, Companywide Quality Control are direct results of this movement.

Quality management is now emerging as a new integrated disciplinary subject among the academic subjects within business administration. Total Quality Management and other theories and techniques represent different approaches in quality management. As an integrated subject quality management has systematically absorbed the knowledge and theories from various scientific disciplines, particularly from organisation and management. In general the systematic body of knowledge of quality management involves at least the following four fundamental aspects:

(1). The organisation structural aspect, i.e. the quality system;

(2). The economic aspect, i.e. quality costs;

(3). The operational aspect, involving quality planning, statistical quality control, reliability and quality engineering, and other operational and engineering tools for quality improvement; and

(4). The human aspect, including subjects such as quality awareness, attitudes and commitment to quality, motivation, quality leadership, employees participation, training and organisational culture.

The human aspect of quality management is the new topic that is drawing attention from many researchers. Quality gurus including Juran, Crosby, Feigenbaum, Deming, and Ishikawa have all stressed the importance of the 'human factors' to the achievement of quality, although the expressions they used are sometimes different (Oakland, 1989). Oakland (1989) point out that quality awareness, commitment, and leadership are essential factors that influence the implementation of Total Quality Management. Lascelles and Dale (1991) have studied the process of quality improvement from the perspective of organisational change. Other authors, such as Davies (1992), Duffin (1992), Lee-Mortimer (1992), suggest that, to achieve Total Quality, it is to change organisational culture.

However, although the current trends in quality management emphasise the aspect of human behaviour, there is a need for more structured scientific research to produce a systematic body of knowledge in this subject.

Quality assurance, as a bureaucratic approach to quality management, emphasises the structural aspect of quality management by establishing a quality system which provides a framework for the organisation of quality activities. The quality system also defines effective operational procedures for process control and planning. A unique feature of quality assurance is that it involves an external body as the certification and surveillance organisation. However, a weak point of quality assurance is that it considers little about the organisation's environment and human behaviour. In the past a few years, a large number of publications have been produced in relation to the subject of quality assurance. Most of these publications are focused on providing guidelines on how to apply quality systems in companies with various technologies (See Chapter 2.3~2.4). Little research has been published to examine the change and the effects that are brought about by the application of quality assurance. One part of this thesis is to study the processes by which fire safety engineering firms adopt quality assurance; to identify the organisational factors, human factors, and environmental factors that affect the application of quality assurance in such firms; and to investigate the organisational change that the fire safety engineering firms have experienced.

Chapter 4 Methodology

This chapter consists of two parts. The first part presents a brief literature review on the methodological issues of management research. In recent years the subject of 'management research' has attracted prominent attention from people who are doing research work in the areas related to management. The purpose of the literature review is to provide a better understanding of the background on which the methodology of the present research is developed. The second part of this chapter introduces the methodology that is employed in the present research.

4.1 Basic Concepts of Management Research

Research on the subject of management started a long time ago. Some remarkable research work such as Taylor's Scientific Management, Fayol' administrative management theory and the Hawthorn Studies have had great impact in the practice of management. However, many management theories are to a great degree the products of practical experience rather than scientific research. In last several decades, scientific investigation into the field of management are greatly promoted by academic researchers, aimed at exploring new theories and verifying existing theories with scientific research methods. Because of the special features concerned with the research process, the methodological issues of management research has emerged as a distinctive subject.

4.1.1 Defining management research

Hull (1952) suggests that science has two essential aspects: the empirical and the explanatory. The empirical aspect is primarily concerned with the facts of the science as revealed by observation and experiments. The explanatory or theoretical aspect, on the other hand, consists in a serious attempt to understand the facts of the science, and to integrate them into a coherent, logical system. From these observations and integration are derived the basic law of the science.

Bennett (1991) further concludes that scientific research is the systematic, careful inquiry or examination that aims at discovering new information or relationships and expanding or verifying existing knowledge for some specified purposes.

Robbins (1983) suggests that when we use the phrase "systematic study", we mean looking at relationships, attempting to attribute causes and effects, and basing our conclusion on scientific evidence, that is, data gathered under controlled conditions and measured and interpreted in a reasonably rigorous manner.

What is 'management research', then? Bennett (1991) offers the following definition: Management research is a systematic, careful inquiry of anything to do with management.

Most of the literature on research methods derive from social science disciplines such as sociology and psychology. In recent years, however, the methodological issue of management research has attracted special attention of some research workers. Management research methodology is emerging as a distinctive academic topic.

Easterby-Smith et al (1991) suggest that management research poses some unusual problems and therefore the general approaches used in research need to be reviewed. They summarise three points, or features, of management research. Although none of these features is unique to management research, their combination makes management research distinctive:

(1). The practice of management is largely eclectic. Despite the progress that has been made towards the creation of distinct disciplines within management, managers need to be able to work across technical, cultural and functional boundaries and draw on knowledge developed by other disciplines such as sociology, anthropology, economics, statistics and mathematics. This raises a dilemma for the researchers: should the subjects of management be studied from the perspective of one discipline, which seems to provide a safer course to gain respectability from academic peers; or should a cross-disciplinary approach be adopted, which is more likely to produce useful results for practical managers.

(2). Access to managers and other staff in some companies can be rather difficult. Any agreement for such access may be accompanied by many conditions about confidentiality and rights to publication, etc. Managers are powerful and busy people. They are unlikely to allow research access to their organisations unless they can see some commercial or personal advantages to be derived from it. Feasible research questions may be determined more by access possibilities than by theoretical considerations. Short interviews are likely to be much more feasible than unstructured observations and discussions.

(3). Management requires both thoughts and actions. Management research should lead to practical actions and consequences. Thus research methods need either to incorporate within them the potential for taking action, or to take account of the practical consequences that will probably ensue.

Bennett (1991) also points out that the scope of management is difficult to define. The processes that are fundamental to management are certainly included in the subject of research. However, there are also many things which are not directly related to the processes of management but have meaningful impacts on management. They may well be the research subjects of other established academic disciplines, but may be studied also by management professionals from the perspective of management. The distinction between what is and what is not management research is not clear.

4.1.2 Approaches to Management Research

There are several summaries of the approaches to management research (For example, Easterby-Smith et al, 1991; Bannett, 1991; Zikmund, 1984.). In general, there are three categories of research concerning with management: pure (or theoretical), applied, and action research.

(1). **Pure (or theoretical) research** is intended to lead to theoretical development. It can be further categorised into three types in terms of the research purposes and outcomes.

Discovery: empirical research that aims at developing new ideas or explanations which enhance knowledge and understanding of the issues of management. This type of research is highly speculative, and outcomes are rare and unpredictable.

Invention: creation of a new technique, method or theory to deal with a particular kind of problems. Many such research activities are based on the direct experience of the inventors, rather than exhaustive field work. Inventions of many famous management theories, such as

Scientific Management and Total Quality Management, fall into this category.

Reflection: examination of an existing theory, technique or group of ideas, possibly in a different organisational or social context. This type of research is popularly used for research work leading to doctoral theses.

(2). **Applied research** is concerned with application of existing techniques and theories to solve a specific problem. It usually involves working with clients who identify the problem. An active area of applied research is management consultancy.

(3). **Action research** is a form of research where action, for example, the solution of a problem which involves some aspects of organisational change and development, is both an outcome of the research and a part of the research process. Classical action research starts from the idea that if you want to understand something well you should try changing it. Action research is most frequently adopted in Organisation Development.

4.1.3 The Philosophical Issues of Research Design

The relationship between the research data and theories is an issue that has been hotly debated by philosophers for many centuries. Two major traditions of views have been 'positivism' and 'phenomenology'.

Positivism believes that the world exists externally and its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition. Methodologies derived from positivism emphasise objective observations and measurement. A typical method of this kind is the 'hypothesis testing' approach of scientific research which starts with a theory, or hypothesis, about the nature of the world, and then seeks data that will confirm or disprove the theory or hypothesis.

On the other hand, phenomenology argues that the world and 'reality' are constructed socially rather than determined objectively. The meanings of the 'reality' are given by people. There are no purely objective and unchanging 'reality'.

Glaser and Strauss (1967) argue that the key task of a researcher is to develop theory through 'comparative method' which looks at the same event or process in different settings or situations. This provides a flexible approach to analyse causal relationships and to gain new insights into facts. It also inspires the use of qualitative data to generate as well as verify theories. They point out that the 'grounded theory', which is discovered from data that are systematically obtained and analysed in research, can usually not be completely refuted by more data or replaced by another theory although they may be modified and reformulated. In contrast, logically deduced theories based on ungrounded assumptions can lead their followers far astray in trying to advance.

Although the basic beliefs of positivism and phenomenology may be quite incompatible, the differences are by no means so clear cut and distinct in actual use of research methods and techniques. Easterby-Smith et al (1991) observe that there is increasingly a move among management researchers to develop methods and approaches which provide a middle ground, and some bridging between the two extreme viewpoints. There are many researchers who adopt a pragmatic view by deliberately combining methods drawn from both traditions.

4.1.4 Research Design and Data Collection

Many research methods that are developed from social science disciplines have been well adopted in management research. Zikmund (1984) summarises four basic methods for data collection that are well used in management research. These are surveys, experiments, use of secondary or 'historical' data, and observation. Gummesson (1991) and Yin (1984) point out that qualitative methods and case studies are becoming increasingly accepted as scientific tools in business research as well as theory construction. Gummesson (1991) also argues that the traditional methods discussed in some standard textbooks that usually consist of desk research and field studies with the aid of survey techniques, experiments, and/or systematic observations, tend to be inadequate for the analysis of the processes of decision-making, implementation, and change. Qualitative methods based on interviews and informal observation, on the other hand, can provide better opportunities for gaining insights into the processes. Particularly, participant observation and action research tend to be accepted in management research as the most advanced methods.

While a research approach is designed, there are a number of factors that the researchers need to consider. Easterby-Smith et al (1991) identify five key factors of a research design: (1) involvement of the researcher; (2) sampling; (3) the relationship between theory and data; (4) experiment or fieldwork; and (5) verification or falsification. Morgan & Smircich (1980) point out that the appropriateness of a research design 'derives from the nature of the social phenomena to be explored'. In general, each research method has advantages and limitations.

For example, informal interviews can be natural and conversational, once rapport is established. The exchange of ideas between the interviewer and the interviewee allows each to develop his views and can introduce points to the researcher which he had not thought of previously. The depth of insight available to the interviewer is not possible to attain by any other method. (Weiss and Rein, 1970) However, the interviewer must be aware that there are at least three sources of distortion arising from the interviews. Firstly, the interviewees may give socially acceptable answers and modify their true attitudes or feelings. Secondly, the interviewer may unconsciously select those responses which reinforce his own assumptions and ignore those data that conflict with his pre-determined model. Thirdly, errors may occur when the interviewer is writing up the interview notes, or coding the interview data. (Dean et al, 1967) Van Maanen (1979) argues that to cope with these potential sources of unreliable data is a formidable task for any researcher moving from his own world to a different one, although awareness of the problems combined with constant self-control can help to overcome them. Whyte (1953) suggests that interviews sometimes demand an element of 'steering' where specific directive questions are more appropriate.

4.2 Methodology for the Present Research

It is determined that the nature of the present research is mainly a re-examination of the existing theories of quality management, particularly the theory of quality assurance, in the context of fire safety engineering. However, some efforts are made to explore the organisational behaviour aspect of quality assurance where no established theory exists. The background and the aims of the research are presented below, followed by a detail discussion of the research methods. Some features of management research which are reviewed in above section have been experienced in the research design. Various methods were used in data collection.

4.2.1 Background and aims of this research

The general background of this research is based mainly on the following three aspects:

(1). The need for better quality has been widely recognised by various industries in the UK. Such a need has also been perceived by the fire protection industry. However, because of the different nature and distinctive features of products and their related industry, the implications of the concept of quality vary from one industrial area to another. Thus, it is necessary to interpret the concept of quality in accordance with the nature and features of fire protection products and services.

(2). Since early 1980s, quality assurance has been introduced into the construction industry as a means of quality improvement. Quality assurance is originally developed from manufacturing activities. It is recognised that modifications are needed while quality assurance is applied to the construction industry and its various sectors (NEDC, 1985; Atkinson, 1987; Ashford, 1989; Griffith, 1990). In the industrial sector of fire safety engineering, a number of quality certification schemes have been established and implemented at certain level and scope (For example, LPCB, 1987a; LPCB, 1987b; LPCB, 1988; BSI, 1986; BSI, 1988a). However, these schemes are limited at the individual sub-systems or components level, and are resulted from practical experience directly. Neither has there been any published theoretical study into the necessity and implication of quality assurance from the perspective of the whole fire protection industry, nor has any research been seen to examine systematically the issues of managing quality of the total fire safety engineering in buildings.

(3). Many fire safety engineering companies have adopted quality assurance for various reasons. Some companies have had their quality systems for years. It is interesting to investigate and to study the causes and effects of the adoption of quality assurance in such companies. These include the reasons and driving forces for these companies to implement quality assurance, the benefits and effectiveness that result from the application of quality systems, and the changes that are brought about by the introduction of quality assurance. It is also interesting to examine the change processes and to identify the factors that affect the effectiveness of quality assurance. It is expected that such a study will produce new knowledge that will improve the understanding of quality management in the fire protection industry, and also improve the understanding on quality assurance in general.

Based on such background, the aims of the research were identified, which can be summarised as follows

- To explore the concepts of quality in the context of fire safety engineering, with special reference to fire safety systems in buildings

- To identify the special features and characteristics of fire protection industry and fire safety engineering that are concerned with the application of quality assurance, and to examine the implications of quality assurance in the fire safety engineering

- To explore the possibility of a systematic approach to quality assurance of fire safety engineering

- To investigate the causes and effects of quality assurance in fire safety engineering firms, and to identify the factors which affect the development and implementation of the quality systems in these firms.

4.2.2. The Present Research Approach

The background and aims of the research define that the nature of the research is the re-examination of the general concepts and theories in a specific area, that is, to examine the concepts of quality and the theories of quality assurance in the context of the fire safety engineering. Therefore, the basic orientation of the research is to explore and develop the existing theory in a new, specified technical and organisational setting, rather than to test the theory.

One of the difficulties encountered in the early stage of the research was to define the scope of the research. There are two major reasons for such a difficulty. Firstly, the complexity of the nature of fire safety engineering and its related industries increases the difficulty of defining the areas for the research. As an academic discipline fire safety engineering is closely related to building and building services engineering, but it also requires essential knowledge and technology from many other science and engineering disciplines. In the context of industrial practice, businesses in fire safety engineering mainly fall into the category of fire protection industry. While having its own industrial characteristics, the fire protection industry overlaps with the building industry, particularly building services. Some firms that deal with systems and components of fire safety engineering are also traders in building services. Secondly, the procurement of a fire safety engineering project, from design to completion, involves a broad range of companies and professionals.

Contributions are made by various members of the building project team. In the practice of building procurement, fire safety engineering is treated rarely as a distinctive package. In addition, quality of the fire safety systems in buildings are not merely the concern of organisations and personnel who are directly dealing with the project, but also the concern of many organisations and social groups that are not within the chain of suppliers and clients, for example, the insurers and the fire authorities.

Despite all these, it is recognised that the research scope should be centred on quality assurance of fire safety engineering in buildings. Fire safety engineering here refers to the assembly of all techniques and facilities that are used in a building for the purpose of achieving fire safety. Particularly, the concept of fire safety systems is defined in this thesis to describe the systematic assembly of such techniques and facilities, and is used as the framework upon which the concept of quality of fire safety in buildings are explored.

After intensive desk research and pilot studies, it was determined that a systematic approach to examine the quality assurance issues in fire safety engineering should include the following four perspectives:

(1). The definition of quality in fire safety engineering;

(2). Quality assurance in fire safety engineering projects;

(3). Quality assurance in fire safety engineering firms;

(4). The macro quality assurance system in the fire protection industry.

Accordingly, research was carried out into these four perspectives.

In the progress of the research, an question arose that how the effectiveness of a quality assurance programme could be evaluated. Attempts were then made to investigate the current practice in evaluating the effectiveness of a quality management programme, and in particular, the current problems in evaluating the quality assurance programmes in fire safety engineering firms.

The objectives of the research in each of the perspectives were determined. Because of the objectives and scopes of the investigation were different in each part of the research, different methods for data collection were used respectively. Both qualitative and quantitative data were used. These include both primary data and secondary data. Detailed methods for data collection are presented below. In general, the research data that support the research findings presented in this thesis were produced by 16 case studies, a questionnaire survey, and a series of interviews with various personnel who represented organisations that have essential relevance to quality assurance in the fire protection industry. Qualitative data obtained from case studies and interviews are used both to develop some hypotheses for research in the later stages, and to explore the facts for building 'grounded theories'.

(1). The definition of quality in fire safety engineering

This part of the research was to study some basic conceptual issues. The purposes and scope were defined as:

- to interpret the basic concepts of quality in accordance to the special requirements of fire safety engineering and to explore that how quality of fire safety engineering can be defined

- to examine how the principles of quality assurance can be interpreted and be applied in the context of fire safety engineering and the related industry

Research work in this part is rather theoretical. The research findings and conclusions are the generalisation of the researcher's understanding and knowledge of the concepts of quality, quality assurance, as well as fire safety engineering. However, research data produced from fieldwork and published literature helped the development of such understanding and knowledge. In particular, discussions with managers and designers during the case studies deepened the understanding of the special features that fire safety engineering and fire industry possess.

Literature that is related to quality assurance in other industry sectors were also studies to allow comparison.

(2). Quality assurance in fire safety engineering projects

While defining quality of fire safety engineering is the essential first step towards quality assurance, assuring the quality of fire safety engineering project is then the essential target to be achieved.

A fire safety engineering project refers to the construction project or package that provides a building with specialised engineering equipment and techniques for achieving fire safety in the building. A fire safety engineering project can be a part or parts of a building project, or a specific engineering project for upgrading the level of fire safety in an existing structure.

Organisation of a fire safety engineering project is a complicated process. It involves various parties within the whole building project team, including the architect, the contractor, the building services engineers and fire safety engineers, and various subcontractors.

A study into the organisation of fire safety engineering project was carried out:

- to identify the stages and components of the organisational process

- to investigate the operation of quality assurance in the projects

- to examine the roles that the various parties play on quality assurance of fire safety systems

- to develop a systematic approach of quality assurance for the fire safety engineering projects

A case study approach was adopted in this part of the research. The cases studied included nine fire safety engineering companies plus two building projects.

It must be pointed out that the problems of feasibility and accessibility limited the number of projects that were studied, but the objectives of the investigation were fulfilled by the studies conducted in the companies. The research data obtained in the case companies were adequate to reveal the facts related to quality assurance of fire safety engineering project. For example, the questions such as how the fire safety engineering projects and packages were organised and managed, and how the quality plans were developed and implemented, were answered easily by managers and engineers of the companies who have actually carried out a lot of projects.

Visits were made to these companies and building sites. Interviews were carried out with various personnel including managing directors, quality managers, operation managers, project managers and engineers, design engineers, as well as site workers. In most cases, quality documents such as quality manuals and quality plans were studied.

Interviews were structured with focused questions on each occasion, but were conducted in an informal way most of the time to allow the interviewees to have relatively free thought flows so that they could reveal points to the researcher which had not been thought of previously. Such interview methods were used almost throughout the whole research.

(3). Quality assurance in fire safety engineering firms

An effective quality system in the fire safety engineering firm is an essential part of the total approach to quality assurance of fire safety engineering, for it has the direct relevance to the quality of fire safety equipment and services that are employed in the building project. Thus, a study of the issues of quality assurance in such companies was an essential part of the research. It provides valuable insights for understanding the process of quality assurance.

The scope of the companies investigated was limited to fire safety engineering firms, that is, the firms that are specialised in one or more areas of fire safety engineering. An obvious reason for such a limitation is that the other companies such as main contractors, architect firms, and building services engineering firms should be studied under the subjects of building and building services.

Aims of the research in this part were:

- to examine the process of the quality assurance programmes in fire safety engineering firms

- to investigate the causes and effects of quality assurance in these firms

- to identify the factors that affect the effectiveness of the quality systems which have been implemented in these firms, and

- explore the human behavioural aspect of quality assurance

Research data included both qualitative data which were obtained through a series of case studies and quantitative data which were produced by a questionnaire survey. Fieldwork was undertaken at three major stages:

(1). Case studies were carried in nine companies. Selection of the companies are made upon suitability, feasibility, and accessibility (Schatzman and Strauss, 1973). Structured interviews were conducted with quality managers, managing directors, division managers, design engineers, as well as operational workers. These produced valuable first hand information about the quality practices in these companies. Opportunities for formal and informal observations were also provided through the visits to the companies' offices and workshops, which formed a part of the data collection process. During one visit to a fire safety systems installation company, formal observation was made on the company's internal quality audit.

Relevant company documents were studied, particularly the quality manuals and written quality procedures.

(2). A questionnaire survey was carried out to gain further information that could not be revealed by case studies and to generalise some findings that had been made through the previous case studies. Because the major purpose of the questionnaire survey was to study the process of developing and implementing quality systems, companies who did not possess certified quality systems were not included in the survey. Questionnaires were sent to all 88 fire safety engineering firms who had registered the quality systems with the Loss Prevention Certification Board (LPCB). Names of these firms were acquired from the "LPC's List of Approved Products and Services" (LPC, 1992) and the journal of "Fire Prevention". 56 valid responses were obtained which formed the data base for analysis. The computer programme "Statistical Program for Social Science" (SPSS) was used for the data analysis. A sample of the questionnaire and a summary of the responses are included in Appendix 2. The problem of bias that may be caused by nonresponse is discussed in Section 7.1.1.

(3). Following the questionnaire survey, five case studies were carried out among the companies who had responded to the questionnaire survey. The major purposes of the follow-up case studies were to gain insights into some facts that were revealed from the survey, and to seek explanations to new questions raised from the survey results.

(4). The macro quality assurance system in the fire protection industry

One of most important features in relation to quality assurance in fire safety engineering is that quality of fire safety engineering is not only the concern of the suppliers and clients, but also the concern of various social groups and organisations that are not within the supplier-client chain. These include the government, insurers, certification bodies, building authorities, fire authorities, trade associations, fire professional institutions, and others. It is essential to study the processes through which these organisations and groups exercise their influence on quality of fire safety systems. Such a study provides a deepened understanding on the social environment within which quality of fire safety systems are achieved.

Some research data were obtained through the fieldwork of case studies and questionnaire survey. In addition, two fire prevention officers were interviewed. On the other hand, most of the necessary information related to the practice of those social groups and organisations in association with quality assurance, were available in published literature and documents that had been produced by relevant organisations.

Apart from the four major parts of the study, attempts were also made to attack the problem of evaluating the effectiveness of the quality assurance programmes. This was in fact a problem of practice rather than theory. Methods and theories for assessing the effectiveness of quality improvement have been researched and used in various business practice. Most of these methods and theories can also be used for the evaluation of quality assurance programmes, although systematic reviews have hardly been found in publications. The problem revealed by the research was that such methods had not be widely used in fire safety engineering companies. Efforts were made to examine these methods and their applicability in the quality assurance programmes in fire safety engineering firms. These included an intensive literature search and fieldwork in eight fire safety engineering firms. Results of the examination are presented in Chapter 9 in the thesis.

Chapter 5 Defining Quality in Fire Safety Engineering

This chapter examines the concept of quality in the context of fire safety engineering. It first reviews some basic concepts and the structure of fire safety engineering and the fire protection industry, and then looks into the features and implication of quality in fire safety engineering. The concepts of 'fire safety assurance system' and 'fire safety system' are defined, and a systematic model for defining quality in fire safety engineering is presented.

5.1 Fire Safety Engineering and Fire Safety Systems: some definitions

5.1.1 Fire Safety Engineering

A general definition of fire safety engineering is 'the application of engineering concepts and techniques for achieving fire safety in a building or any other structure' (Malhotra, 1991).

The overall objective of fire safety engineering is to provide buildings with technical measures and facilities that have been designed and engineered to provide and maintain an adequate level of fire safety. This objective involves three major aspects:

(1) protection of life;
(2) protection of the building and its contents;
(3) prevention of conflagration.

Woolley (1993) points out that fire safety engineering currently means many things to different people:

> "At one level it can mean the calculation of the structural response of a building element (such as a beam or a column) from a knowledge of the material properties at elevated temperatures, the temperatures it achieves, the loads acting on it and so on.
>
> At a more strategic level, fire safety engineering can mean a package of measures which has the objective of reducing the potential for injury, single deaths and multiple deaths in and nearby the building to an acceptable level."

As an academic discipline, fire safety engineering covers a wide range of topics that are related to fire safety. These topics can be very different in nature and are derived from very different academic subjects. Marchant (1983) suggests that forty-six disciplines and professions hold, or can produce, information which is useful input to fire safety engineering. Rasbash (1981) defines fire safety engineering to include 12 subject areas:

1. Fire Chemistry.
2. Fire Dynamics
3. Fire Protection Engineering (Active)
4. Fire Protection Engineering (Passive)
5. Interaction Between Fire and People
6. Fireground Operations and Appliances
7. Fire Investigation
8. Fire Safety Assessment and Measurement
9. Fire Safety Design and Management of Consumer Items and Energy Sources
10. Fire Safety Design and Management of Buildings
11. Fire Safety Design and Management of Industrial Processes and Transport
12. Fire Safety Design and Management of Cities and Communities.

The Institution of Fire Engineers offers a list of areas for the study of fire engineers, which consists of

Scientific problems,
Sociological problems,
Technological problems,
Management problems, and
Legal problems.

The term 'fire science' is used particularly to refer to the scientific research activities that provide fundamentals of systematic and formulated knowledge for fire safety considerations. Woolley (1993) defines that 'fire science describes the processes which occur when combustion takes place under uncontrolled conditions'. It draws on knowledge from a wide range of basic science, from combustion science to toxicology and behavioural science. Recognised topics of fire science include Fire Physics, Statistics and Risk, Fire Chemistry, Translation of Research into Practice, Structures, People and Fire, Special Fire Problems, Smoke Movement, Detection, and Suppression(Cox and Langford, 1991).

In this thesis, a working definition of fire safety engineering is given as the application of engineering techniques, technologies and facilities in buildings and any other structures for the purpose of achieving fire safety.

This definition emphasises the application of the engineering concepts and techniques as well as the equipment and facilities for the achievement of fire safety. While this thesis is entitled 'Quality Assurance in Fire Safety Engineering', it studies not only the quality of engineering design but the quality of engineering equipment and facilities that are used in buildings for fire safety.

5.1.2 Fire Safety Assurance Systems and Fire Safety Systems

A concept that is closely related to fire safety engineering is the 'fire safety system'. The terms 'fire safety system' and 'fire protection system' are used very often by fire safety professional. However, sometimes they can mean quite different things. In some circumstances they are used by fire engineering designers and researchers to refer to the integration of all the fire safety means provided for a building, which includes not only engineering techniques and facilities but also managerial measures, while in other occasions it is most commonly used by industrial practitioners as a general title for various discrete systems such as: 'fire alarm and detection systems', 'fire extinguishing systems', and 'passive fire protection systems'.

In this thesis, the concept of 'fire safety assurance systems' is to be introduced. A working definition of the fire safety assurance system is given as the total outcome of the integrated application of all the technological and managerial measures that are used in a building for the achievement of fire safety. It includes both the engineering aspect and the managerial aspect.

The objectives of a fire safety assurance system include:

- Control of ignition
- Detection of fire
- Control of fire growth and spread
- Provision for escape
- Control of smoke movement
- Protection of the building structure
- Provision of fire fighting facilities and access
- Fire safety management

The structure of a fire safety assurance system can be described as a combination of two sub-systems: a 'hardware' sub-system which consists of all the fire protection equipment and facilities that are used in the building for passive fire protection, fire detection and alarm, fire suppression, smoke control, etc.; and a "software" sub-system which consists of managerial measures for fire prevention, such as training of staff, operation and maintenance of equipment, and emergency planning. Figure 5.1 shows the typical structure of a fire safety assurance system.

The 'hardware' sub-system of the fire safety assurance system is referred to as a 'fire safety system' in this thesis. A working definition of the fire safety system is given as the total outcome of the application of engineering techniques and facilities that are used in a building for the purpose of fire safety. It is the outcome of fire safety engineering applied in the building.

The basic structure of a fire safety system can be described as an open system with distinct but interdependent sub-systems. Some typical fire safety sub-systems are passive fire protection systems, fire detection and alarm systems, fire suppression systems, evacuation systems, smoke-control systems, and emergency lighting systems. They are shown in Figure 5.1. The structure of fire safety systems may vary from building to building as the fire safety requirements of individual buildings are different. Some of the sub-systems shown in Figure 5.1 may not appear when they are not required in a simpler building.

It must be pointed out that the concept of 'fire safety systems' introduced here is rather theoretical. In the current practice of design and construction, fire safety systems are usually not be treated as integrated systems.

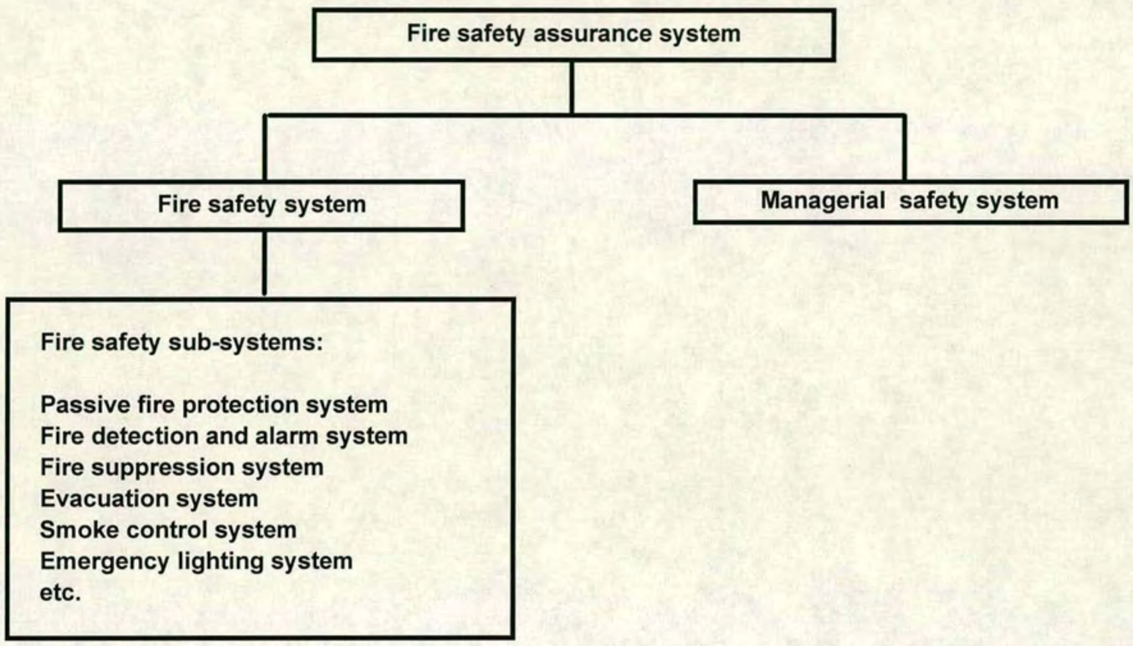

Figure 5.1 The structure of a fire assurance system

However, there is a need for the recognition of the overall fire safety measures in a building as an integrated system. In this thesis, the concept of fire safety system is used to describe the outcome of fire safety engineering in buildings.

5.2 Fire Protection Industry

Quality is a concept that is relevant to both engineering and management. To study quality assurance in fire safety engineering, it is necessary to review the context of the industry that is related to fire safety engineering, that is, the fire protection industry.

The fire protection industry generally refers to the industrial sector that is involved in production of fire protection equipment and facilities. Defined by the complex nature of the fire safety issues, the fire protection industry poses a complicated structure.

The fire protection industry offers a wide range of products from fire-resistant building components to portable fire extinguishers and fire fighting vehicles. Business activities of companies in the industry involve design, manufacture, installation, commissioning and maintenance. Company sizes vary from less than ten to several hundreds employees.

Within the fire protection industry, there are a number of distinct industry branches. These industry branches are formed on the basis of products and services groups. This results in the formation of various trade associations within the industry. Examples of these trade associations include British Fire Protection Systems Association (BFPSA), Fire Extinguishing Trades Association (FETA), British Automatic Sprinklers Association (BASA), and Fire Fighting Vehicle

Manufacturers' Association (FFVMA). Meanwhile, some sections of fire protection industry are interrelated and overlapped with other industries, for example, smoke control section with the ventilation industry, emergency lighting section with the lighting industry.

In a recent research (EDMC, 1990), the unusually diverse nature of the 'fire industry' was recognised. The scope of the fire industry is proposed in the research report, which involves:

> "Management, operations and training of local authorities, fire brigades, including statutory inspection and fire investigation;
>
> Management, operations and training of military, airport and industrial fire brigades, including fire investigation;
>
> Suppliers of fire safety plant, machinery and equipment, including design, manufacture, sales, testing, installation, training, commissioning and maintenance;
>
> Consultancy, design and specification of fire safety aspects of buildings, structures, products and processes, including architects, structural engineers, fire safety consultants and related specialists;
>
> Fire safety operations in industry and commerce (non brigade activities);
>
> Fire safety education, training and fire protection advice;
>
> Fire insurance and risk evaluation;

Other areas of importance to the fire industry, including fire research, provision of professional advice on the development of standards, codes of practice, and legislation."

To some extent, the complex structure of the fire protection industry makes it very difficult to examine the quality assurance issues of the industry as a whole. The scope of present research is restricted within the industrial areas that are directly relevant to the fire safety engineering in buildings. Therefore, while the definition of quality is concerned in the context of fire safety engineering, it is focused on the defining the quality of fire safety systems.

5.3 Quality of Fire Safety Systems

The word 'Quality' is often linked with the sense of 'excellence', 'fineness', 'value-for-money', as well as terms such as 'function', 'reliability', and 'durability'. In Chapter 2.1 some definitions of quality have been reviewed. These definitions reflect different emphases on the perception of quality from various perspectives of production activities and nature of products. The perception of quality is something both subjective and objective. To different products or services, quality does not always mean the same. To make quality 'manageable', it is necessary to defining quality in accordance to the specified products and the processes that are involved. The remaining part of this chapter examines how quality of fire safety systems can be defined.

5.3.1 Features

Before we examine the meaning of quality of fire safety systems, it is necessary to look into some features of fire safety systems:

(1). Every fire safety system is a 'unique' product. The requirements for fire safety systems vary from one building to another. Therefore, the structure and performance of fire safety systems change according to the requirements and conditions of the buildings. Few fire safety systems are ever repeated exactly.

(2). The quality of a fire safety system has a special social meaning. The purpose of fire safety systems is to provide fire protection to life and property. Failure of a fire safety system in the case of a fire could cost a great deal more than the value of the system itself. It may result in severe damage of the building and its contents. It may also cost human life and result in a great social impact.

(3). The performance requirements of fire safety systems are regulated, in part, by the statutory authorities. In many cases, specification of fire safety systems is mandated rather than required by the clients on a voluntary basis, although the clients usually have their own choice of the system designers, installers and component suppliers. In some cases, clients may be reluctant and feel that they are being asked to spend too much money on such systems.

(4). Quality of fire safety systems is the concern of customers and suppliers, as it is usually the case with ordinary consumer products. In addition there is a great interest by other parties who are out of purchase-supply chain, such as building authorities, fire authorities and insurers.

These features largely influence the way in which the requirement of a fire safety system is defined and the way in which quality of the fire safety system is perceived and measured.

The following sections of this chapter present a systematic model for defining quality of fire safety systems. This model is developed by the generalisation of the aithor's understanding and knowledge of the concept of quality, quality assurance, and fire safety engineering. Fieldwork carried out throughout the study help the development of such understanding and knowledge.

It is suggested that the systematic model for defining quality of fire safety systems including two perspectives (as shown in Figure 5.2): (1) Quality dimensions; (2) Quality processes. Quality dimensions define the interpretation and measurement of requirements to a fire safety system, while quality processes describe the requirements to the production processes through which quality dimensions are achieved.

5.3.2 Quality Dimensions

It is suggested that the requirements to a fire safety system can interpreted into and measured on the following six dimensions:

(1). Performance,
(2). Reliability,
(3). Durability,
(4). Maintainability (or Serviceability)
(5). Economy
(6). Aesthetics

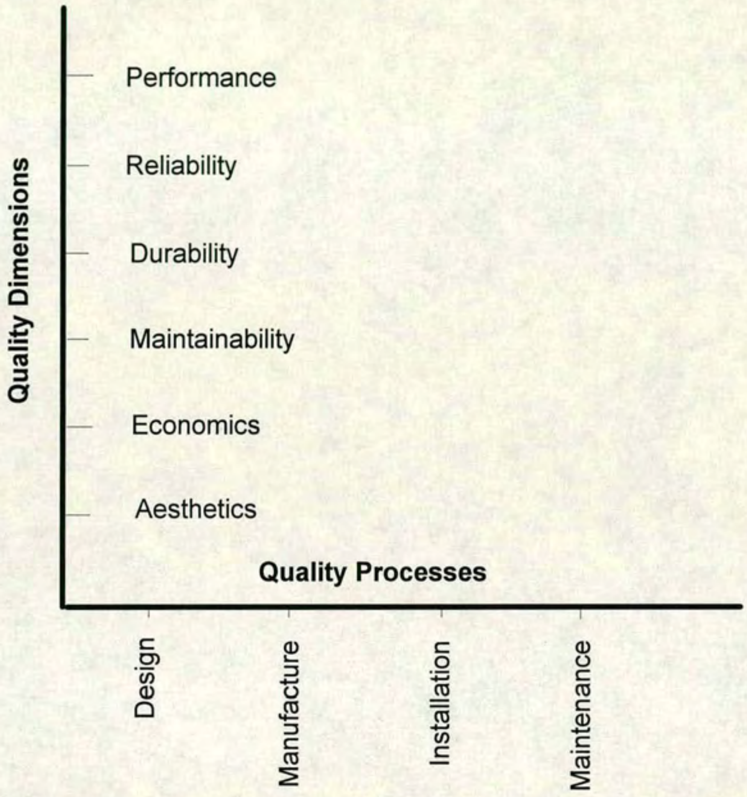

Figure 5-2 A Model of Quality of Fire Safety System

Performance

Performance refers to the functional characteristics of a product or system. It reflects the basic purposes of the product or system. It can be defined clearly in product specifications.

Performance of a fire safety system is defined by the total fire safety requirement of the building. While performance of each fire safety sub-system is measured against its functional specification, performance of the whole system is measured indirectly by the totality of the performance of the sub-systems. Performance is not an unfamiliar term in fire safety engineering. The traditional fire tests are mainly concerned with the performance of fire products and materials.

One of the problems that remains in current practice is that the sub-systems and components of a fire safety system are designed and installed separately by different professionals because of the industry tradition. Lack of co-ordination between these participating parties could result in an uncoordinated total system, which means that, when the whole system is brought together, it may not function as it is expected. Therefore, it is important to have a clear specification in the early stage of design to define all the functioning requirements to the system. It is also important to co-ordinate the procurement of all the sub-systems throughout the whole construction process from design to commissioning and completion.

Performance is the basic measurement of quality, but high performance does not always mean better quality. For example, a fire resistant door with high performance of fire resistance may be in poor quality if it is easy to break in daily use, or its appearance is detrimental in the environment where it is used. When quality of a fire safety system is evaluated, assessment should be made not only of its performance, but of other quality dimensions.

Reliability

Reliability reflects the probability that a product or system fails to perform consistently over an expected time period. Reliability of a fire safety system is not only as important as that of any other engineering system, but it has some special meanings.

(1). Failure of a fire safety system at different times can bring about very different results. For example, failure of a fire detection system in the event of a fire could result in loss of life while failure of the same system during testing may cost little.

(2). Different types of failure of a fire safety system mean different results. A fire alarm system fails to give warning when a fire occurs can be far more harmful than a false alarm. Failure of different system components or sub-systems can also result in different consequences.

(3). Some fire safety systems may never have a chance to perform their functions simply because a fire never occurs. In other words, their failure may never be known. For example, a fire door may reduce its capability of fire resistance for some reasons after it has been installed in a building for some time. But this reduction of resistance may not be known since it may never be exposed to a fire in its useful life.

Durability

Durability is the measurement of life span of a product or system. Theoretically, the life span of a fire safety system is expected to be as long as that of the building in which it is installed. But some components will inevitably need regular maintenance and other parts may need to be replaced over time.

While some components of a fire safety system, such as fire doors, structural fire protection, and smoke control equipment, may have multiple functions. The durability of the fire safety functions of such components should be distinguished from their other functions. In a building, it is hard to believe that a fire door would still perform to the same standard after 20 years in use as when it had just been installed.

There are many difficulties to define the quantitative measurement of durability. Some current fire performance tests do take durability into consideration to some extent. For example, BS 476 requires that the factors of material sensitivity to time and moisture are taken into consideration when the test specimen is prepared (BSI, 1987c). However, the measurement of such factors are set more or less on an experimental basis.

Maintainability (or Serviceability)

Some components and sub-systems of a fire safety system require regular maintenance throughout their life. The long life span of a building requires its fire safety system to be as durable as the building itself. Variations of the durability of components and sub-systems mean that some components will need to be replace with new ones. Therefore, it is important to the whole fire safety system that it is designed and constructed in a way that it is easy to be maintained.

Some fire protection products and systems are easy to maintain, while others clearly are not. A high quality fire safety system should be one that can be maintained easily. Availability of maintenance services is also a characteristic of maintainability. Once a problem emerges within a system, maintenance service should be available so that the problem can be fixed promptly.

Economy

Although it is easy to understand that a good fire safety system should be economic, it is difficult to define a "cost-effective" system before some fundamental research work have been done. Currently, many of the existing fire safety systems are unlikely to be cost-effective. Many buildings are possibly "over-protected". A research conducted in Australia suggests that a saving of $200 million per year could be achieved there without reducing the current level of safety in high rise and other buildings (Beck, 1989). The research also suggests that the traditional design approaches which are currently used for fire safety system designs are unlikely to result in the most cost-effective outcome.

Aesthetics

To some extent, aesthetic characteristics of the fire safety systems are not as important as their functional characteristics. Lack of aesthetics in a fire safety system will not influence its fire performance. But aesthetics reflects a degree of excellence and may affect the building's overall fitness for use.

Although this is a subjective area, basically the appearance of the system should be pleasing and the component should fit in with the rest of the building. The degree of pleasure and harmonisation will be judged by the viewer's own preference. But the system designers as well as the component producers should take the aesthetic aspect into account.

5.3.3 Quality Processes

Quality is not achieved by inspection. Nor is it achieved by design or manufacture alone. Quality is built in throughout the whole production process. The word 'production process' here is used in a broad sense, which involves the activities from design, manufacture, to service and maintenance. Quality of products relies on quality of these production activities involving design, manufacture, installation and maintenance.

The production process of fire safety systems usually involves design, manufacture, installation, and maintenance. Quality in each stage of the production process has specific implications and emphasises different aspects of requirements. To understand quality of fire safety systems, it is essential to understand the quality implications in each stage of the process.

Quality of Design

The essence of quality is to satisfy the consumer's requirements. In the process of design, it is essential to interpret exactly the requirement from consumers and to translate them into product design and specification.

Juran (1979) suggests that 'quality of design' can be regarded as a composite of three separate steps in a common progression of activities:

1. Market research: to identify what constitute quality to the consumer, or in other word, what the consumer needs;

2. Concept: to choose a concept of product or service to be responsive to the identified needs of the consumer;

3. Specification: translation of the chosen product concept into a detailed set of specifications which will meet the consumer's needs.

There are two different sorts of design activities that are involved in fire safety engineering: design of the fire safety systems and sub-systems in building projects; and design of fire safety products and system components for manufacturing. While there is not much difference between the design processes of fire safety products and those of other manufactured products, the design processes of fire safety systems and sub-systems in buildings are similar to those of buildings and building services which include stages of initial briefing, detailed design, and material specification.

One of the features of fire safety systems is that its quality is not only the concern of clients and suppliers, but also the concern of other parties such as government, regulatory bodies, and insurers. It is very important for the designers to consider the requirements from all aspects.

Quality of design is measured by the conformance of the designed drawings or prototype and specifications with the true requirements of the system and components.

Because of the complex structure of the fire safety system, the fire safety sub-systems are designed and installed by different sub-contractors. While they are brought together, they should be able to co-operate and meet the integrative requirements of the total system, as well as the requirements of the building. At present the co-operation of fire safety sub-systems is a vulnerable area where quality problems are relatively easy to occur. It is the designer's responsibility to ensure the co-ordination of the total system.

Quality of Manufacture

Quality control and quality assurance were developed originally from manufacturing activities. In the construction industry, quality assurance was first introduced into the are of supply and manufacture of building materials and components.

While fire safety products and system components are designed to meet requirements of all aspects, it is essential to ensure that they are manufactured in accordance with the design. Quality of manufacture then is conformance to design and specifications. Understanding the concept of conformance simplifies the management of quality of manufacture and makes it measurable.

Quality of Installation

In the process of installation, components and sub-systems of fire safety systems are assembled and tested so that they operate in the specified manner. The installer should ensure that all the components and sub-systems are assembled in such a way that they are conforming to the design drawings and specifications. At this point, quality of installation is much similar to quality of manufacture which is also 'quality of conformance'(Juran, 1979).

However, the design and specification of fire safety systems vary from one to another. So do the site conditions. It is reasonable to say that every installation is 'unique'. It should be assured that the installers understand clearly all the details of the design drawings and the work instructions. Communication between the designers and installers is extremely important throughout the installation process.

While the co-operation among fire safety sub-systems is a important concern of the designers, it is the installer's responsibility to ensure that the installed systems will fulfil such co-ordination.

Quality of Maintenance

Quality of maintenance can be defined as conformance of the products or system to the quality standards over time.

Quality of maintenance is an essential part of the total quality of fire safety systems. While fire safety systems are to function properly over a certain long time period as they are so required, many parts of the systems need to be maintained regularly. Quality of the maintenance is just as important as quality of design, manufacture, and installation. Without proper maintenance, some parts of the systems may loss function and the quality levels of the systems would decrease.

Some fire safety sub-systems, such as automatic sprinkler systems, and fire detection and alarm systems, are contracted to specialised maintenance services. The quality requirements for the maintenance services should be described clearly in the contract documents. The maintainers must ensure that the systems are maintained in accordance with these requirements.

Responsibility for maintenance of the total fire safety system is rested with the users of the building. Technical as well as managerial measures should be taken to ensure that the system is kept up at the satisfactory quality level. Requirements of and responsibilities for maintenance should be defined in the building safety management manual or documents of this kind, and be implemented and reviewed.

Competence of Professionals

An issue that is fundamental to quality of all the processes discussed above is the competence of the professionals who carry out the actual work of design, manufacture, installation, and maintenance.

Competence of professionals is defined as the ability to perform the functions of an occupation. Traditionally, it is assessed by trades and professional bodies through qualification examinations and elections of members. Professional examinations and qualifications related to fire safety are available from a number of organisations, for example, Institution of Fire Engineers, Fire Services Examination Board, Institute of Fire Prevention Officers, Fire Protection Association, and Fire Extinguishing Trades Association.

With the objective to develop a new structure for vocational qualifications, initiated by the Government, the Fire Industry Lead Body has been developing its standards of competence and are working towards the establishment of a national vocational qualification system within the fire protection industry (Jerome, 1993).

A particular difficulty in the development of qualification schemes in fire safety engineering is concerned with the unusually diverse nature of the subject. For example, as the British Fire Protection Systems Association suggests, there is no generally available qualification which would be seen as qualifying a person to work in all the technical and professional areas handled by BFPSA members (EDMC, 1990). There are numerous types of competence required in typical member companies of BFPSA, including trade skills for installers, manufacturing skills for factory employees, and design skills for designers. A coherent set of qualifications for the whole of fire safety engineering that are nationally acceptable are still to be developed.

Chapter 6 Quality Assurance in Fire Safety Engineering Projects

This chapter presents the results of the research that was carried out from the perspective of building projects. It is recognised that fire safety engineering is a distinctive part of a building project that needs special attention. In the research, features of quality assurance in the context of fire safety engineering were investigated. The procurement processes of fire safety engineering in building projects were examined. The stages and components of the procurement process have been identified and the roles played by various parties in the quality assurance of fire safety systems have been studied.

Case studies were carried out in fire safety engineering firms as well as building projects. Interviews were conducted in these companies and building sites with various personnel including quality managers, managing directors, project managers and engineers, production and operation managers, design engineers, as well as site workers. In most cases, quality documents such as quality manuals and quality plans were studied. These field work provided valuable first hand information of the quality practice in the industry and helped to gain insights into the matters of quality assurance in fire safety engineering and in building projects.

A systematic framework for quality assurance of fire safety engineering in building projects is developed, which involves three aspects: (1) total system quality planning, (2) sub-system quality planning, and (3) quality systems in fire safety engineering companies.

6.1 Features of quality assurance in fire safety engineering

Quality assurance is developed originally from the manufacturing industry. It is recognised that it needs further modification and development while it is introduced into construction industry. Research has been carried out to study the special features of the construction activities so that quality assurance can be implemented effectively within the industry. These special features are reviewed and summarised in Chapter 2.4. With these special features, the construction industry has to make its own interpretation of the quality systems and to develop quality assurance guidance for its special activities and particular sectors.

As a part of the construction industry, fire safety engineering shares with the other sectors of the industry all these features above. However, as a particular sector of the industry, fire safety engineering retains some distinctive characteristics:

(1). In a building, the fire safety system and its sub-systems are interrelated with many other parts of the building. Therefore, they are not only the concern of fire safety engineers but also of many parties in the project team such as the architects, structure engineers, main contractors, and building services engineering contractors.

For example, emergency lighting systems are closely linked to illumination and electricity supply systems; sprinkler systems are interconnected with the water supply systems; smoke control systems are overlapped with ventilation and air conditioning systems. Therefore, co-ordination between fire safety engineers and building services engineers is essential to the achievement of quality in these systems. On the other hand, designs of passive fire protection, fire compartmentation and evacuation accesses are mainly the concern of architects, structural engineers and building services engineers, while fire safety specialists may be consulted for expertise in some complex buildings.

(2). The procurement of a fire safety system is segregated into several parts which are undertaken separately by different specialists. In a typical building project, each fire safety sub-system is designed and installed by specialised subcontractors. These subcontractors may enter contracts with various parties, such as the building client, main contractor, project manager or building services subcontractor, varying with the building procurement system that is used for the project. These subcontractors are likely to be brought into the building project at various stages. Ways of communication and co-ordination between them depend on the organisation of the building project.

(3). The traditional building technology limits the possibility of managing the design and installation of all fire safety sub-systems within one integrated package, although the development of fire safety engineering provides a possible new way for fire safety design. Problems are often raised by the separated procurement of fire safety sub-systems.

(4). Many specialised fire safety subcontractors are small companies. Organisation structures in these companies are simple, and communication and interpersonal relationships tend to be easy and informal. Formal quality assurance structures and procedures may not fit well with the company's culture.

(5). Fire safety engineering companies are usually subcontractors in a building project. However, many small fire safety companies do not maintain fully employed installation teams. While design work are carried out by design engineers, installation labour is acquired by further subcontracting.

(6). Fire safety in buildings is regulated by various statutory authorities. Insurers also exercise powerful influence throughout the process of design, specification, material purchase, installation and commissioning. Involvement of the statutory bodies produces meaningful results in quality assurance of fire safety systems.

(7). Maintenance of fire safety systems in buildings are carried out regularly throughout the life of the buildings. It is regulated by the fire safety laws, and inspected and certified by local fire authorities.

(8). In some existing buildings, fire safety systems are refurbished and new systems are installed to upgrade fire safety standards or to meet new requirements to the changed purposes of the buildings. Organisation of such projects is likely to be less complicated than new building projects, but the technological works can be more demanding.

All these features above are greatly concerned with the application of quality assurance in fire safety engineering. The Quality Systems that are described in ISO9000/BS5750 and in other supplements developed by some certification bodies provide guidance for quality practice in fire safety engineering companies. However, a broader approach is needed for quality assurance of fire safety engineering in building projects.

6.2 Procurement of fire safety systems in building projects

Organisation of the fire safety engineering package in a building project is largely concerned with the building management system that is used for the building project. To understand the organisation and management of the fire safety engineering package, it is necessary to examine the procurement process of fire safety systems in the context of building project management.

There are several type of building procurement systems that are currently used for contracting and managing building projects. The major building procurement systems can be summarised as: the traditional system, construction management for a fee, package deal systems and design-and-build, separate contracts, project management, and the British Property Federation (BPF) System.(Franks, 1984; Turner, 1990)

It was suggested at the early stage of the research that organisation of fire safety engineering packages in building project is affected by the building procurement system used for the projects. This was confirmed by the results of the field study. During the case studies, discussion were held with project managers, quality managers and project engineers to enquire about the way they were involved in the projects under each form of building procurement systems. The research results showed that the procurement processes and procedures of fire safety engineering change from project to project. These will be discussed in the following paragraphs. In the meantime fire safety engineering subcontractors tend to formulate their working procedures to limit the variation caused by the influence of building procurement systems. It is possible to generalise the common procedures that the fire safety engineering packages are procured.

In regard to the practice of quality assurance in building projects, the research results suggested that there are some features that are concerned with quality assurance practice in each form of building procurement systems. Based on the generalisation of the procurement processes, a systematic framework for assuring quality of fire safety systems in building projects can be developed to provide general guidance for managing quality of the projects. The framework is described in Section 6.3. Principles and methodologies for quality planning are presented which are hoped to be valuable for the development of detailed quality plans and quality procedures for specific types of procurement.

The following paragraphs examine the impacts of the major building procurement systems on the procurement of fire safety systems and on quality assurance of fire safety engineering in buildings.

The traditional system

The traditional system has been one of the most popular practice of managing building projects for centuries. More recently, it is named as the Standard Form of Building Contract with Quantities. The procurement process can be summarised as the following:

(1). The client provides the architect with his requirements for the building and the maximum of the cost;

(2). The architect prepares alternative proposals for the client, while the quantity surveyor estimates the costs of the alternatives;

(3). The client accepts a proposal;

(4). The architect consults specialists such as structural engineers, landscape architects, building service engineers, and fire safety engineers; and prepares drawings and specifications;

(5). Tendering;

(6). The main contractor who enters the contract sets up the site management system and procures specialised sub-contractors;

(7). The contractor and sub-contractors carry out and complete works.

In this process, there are three key points that are especially important to the achievement of quality:

(a). All dimensions of quality of the building should be defined clearly and perceived correctly. The client's requirements for the building must be specified in the building brief in details. As clients usually have limited expertise in building technology, it is the architect's responsibility to ensure that the client's requirements are specified clearly and are achievable technically. While necessary, the architect, together with other experts, should advise the client on the aspects of quality requirements that are not considered by the client.

(b). Quality requirements of all dimensions should be precisely interpreted into design drawings and specifications. It is essential to ensure that all members of the design team understand clearly the requirements defined in the brief and develop the design accurately according to the brief. Co-ordination and communication within the design team should be well maintained so that the interfaces of different parts of the design can be controlled and the quality standards can be implemented throughout the process.

(c). The design should be precisely perceived by the main contractor and the sub-contractors, and fulfilled throughout the construction process. One of the most distinctive features of the traditional procurement system is the separation of design and construction. The design stage is usually completed before the construction process commences. Many problems could occur at the interface between design and construction. Quality assurance measures must be taken to ensure that the building is constructed to the quality requirements which are interpreted in the drawings and specification.

In the aspect of fire safety engineering, quality is pursued throughout the total process from briefing to construction. Fire safety specialists may be consulted at the briefing stage for the fire safety requirements in the building. Fire safety design has to meet the compulsory requirements specified in the Building Regulations, and has to be approved by local authorities before the design is put for construction. While the architect is responsible for the conceptual design of the fire safety system, fire safety sub-systems are usually designed, installed and commissioned by specialised subcontractors. To assure quality of fire safety systems, quality plans should cover the overall process from conceptual design to commissioning. Details of the quality plans are discussed later in this chapter.

Construction management for a fee

Construction management for a fee is often referred as 'Management contractor', or 'Management fee contractor'. In this system, the management contractor does not carry out construction works, but is employed by the client as a management specialist to control the construction project. Operational procedures of the system involve:

(1). The client discusses his needs with the architect and quantity surveyor, and accept a proposal from them, as they do in the traditional system;

(2). The architect and quantity surveyor prepare drawings and bills, and send them to management contractors for tender;

(3). The accepted management contractor joins the design team;

(4). The design/management team develops designs, and organises work packages;

(5). The management contractor sets up its management system and plan;

(6). Sub-contractors tender for work packages;

(7). Work packages are carried out as planned.

Quality assurance in this system is mainly the responsibility of the management contractor, while the architect and quantity surveyor play the very important role of interpreting the client's need. Quality assurance guidance for management contractors have been developed by certification bodies and implemented successfully.

Quality of fire safety engineering must be pursued throughout every stage of the building process. Sub-contractors who design and install the individual fire safety sub-system are brought into the project at various stages, but the special role of the management contractor is likely to provide a better chance for controlling and co-ordinating the sub-contractor's work. Quality assurance plans should be managed by the management contractor, and sub-contractors implement the quality plans under the monitoring of the management contractor.

Package deal system and Design-and-build

The package deal system sometimes is called 'turnkey system'. Package dealers are responsible for the total design and construction process, and offer clients with 'completed buildings' rather than 'designs', 'management services', or other individual 'services'. It is being used increasingly for non-prestigious buildings, such as industrial, commercial and 'repetitive' buildings. The operational procedures of the package deal system can be described as the following:

(1). The client defines his requirements for the building, and seeks proposals from package dealers;

(2). Dealers and the client negotiate on the proposals and amendments may be made;

(3). The client accepts the proposal from one of the dealers, and the dealer enters the contract;

(4). The dealer completes detailed design, and carries out and completes the works.

The design-and-build system is similar to the package dealer system. Major procedures of the procurement process in the design-and-building system are the same with those in the package deal system as they are described above. The principal difference between these two is that package dealers deal frequently with semi-standardised building-forms, whereas design-and-build contractors offer services to any type of buildings to meet client's requirements.

The package deal or design-and-build contractors assume the full and sole responsibility for quality of the building projects. Because the contractor is able to control and co-ordinate the design and construction process, it is easier to control some of the problems that are caused by the separation of design and construction. The close relationship between the designer and builder tends to reduce variations in construction from the original design. Prompt responses are possible to rectify any design defects found in construction.

Fire safety specialists and sub-contractors may be invited to join the design team, and co-ordination among designers and installers of fire safety sub-systems can be improved.

Separate contracts

The separate contracts system is sometimes referred to as 'Alternative Methods of Management', in which the architect designs the work to meet the client's needs and arranges contracts, on the client's behalf, with a number of separate contractors. Like other systems, it commences with the client's need for the building, and progresses as the following:

(1). The client briefs the architect on his requirements;

(2). The architect and other consultants prepare the design to the point where some works can commence;

(3). The architect and quantity surveyor arrange contracts with specialist contractors for some work, while the architect continues design of other works in parallel;

(4). Specialist contractors carry out and complete their works, while the architect and quantity surveyor arrange further contracts with other specialist contractors for works now designed, and continues design of other work;

(5). The process continues until design and construction are completed.

In this system, the client enters contracts with a number of specialist contractors including the fire safety specialists, and has a close involvement in the project throughout its whole life. Lines of communication between the client and the specialist contractors are direct and short. This enables the client have effective control over the contractor's work and make prompt response to unforeseen site problems. Expectation to quality are delivered directly from the client to the specialist contractors and the work are inspected by the client or his consultants. Experience suggests that sub-standard work occurs less frequently than on projects where 'traditional systems' are used (Franks, 1984). However, separate contracts may cause difficulties in co-ordination among individual contractors. Responsibilities to quality must be clearly defined in contracts and project quality plans. Interfaces between separate contractors should be well controlled.

Project management

The project management system is often used for large and complex building projects. In this system, a project manager is appointed to manage the project on behalf of the client. The project manager is a distinct member of the construction team whose job is to co-ordinate various parties involved in the building project. A significant difference between the project management system and the others described is that the client's principal contact is with the project manager.

The procurement process can be briefly described as

(1). The client specifies the requirements for the building, and appoints a project manager;

(2). The project manager co-ordinates the team of experts to appraise alternative project proposals which include the selection of contracting system, and advises the client;

(3). Once a proposal has been chosen, the project manager, in consultation with the client, arranges the tender and contracts. The type of contracts may be traditional competitive tender, or Management for Fees, to meet the best interest of the client.

(4). The rest of the process follows the procedures of the traditional system or management for fees system, with the project manager working as the client's representative to manage the contracts and to co-ordinate between contractors and the client.

Project management has some special features that are advantageous to the improvement of quality in building. The client's only link with the project is the Project Manager. The Project Manager deals with all other project parties. It reduces interfaces and provides better control. The Project Manager works as a management expert who is not involved in any detailed technology of design and construction. This allows him a better continual focus of attention on quality throughout the various stages of the project. Griffith (1990) suggests that the structure and organisation of a project management approach integrate the various aspects of design and construction process and provide constant feedback which ensures that defective work is identified and rectified at early stage.

The British Property Federation System

The British Property Federation System is introduced in 1983 in the UK with the publication of a 'Manual of the BPF System for building design and construction' which sets out the operation of the system in detail (Franks, 1984). In this system, a Client's Representative is appointed to manage the project on behalf and in the interests of the client. The Client's Representative can be a person or a firm. He may be an employee of the client, an architect, a chartered surveyor, an engineer or a project manager. In addition, a Design Leader is employed to take the overall responsibility for the pre-tender design and for sanctioning the contractor's design. Like the Client's Representative, the Design Leader may be an individual, a multi-disciplinary firm, or a general consultant with specialist consultants contracted to him. The operational process of the system can be divided into five major stages:

(1). Concept: The client plans to build, examines alternatives at minimum cost, ascertains economic viability and feasibility, and appoints the Client's Representative.

(2). Preparation of the brief: The client and the client's representative develop the building brief and cost plan in outline. A Design Leader is appointed to be responsible for design.

(3). Design development: At this stage, the design leader first co-ordinates consultants to develop the building brief for outline planning permission from the local authority, while the client's representative monitors the design progress, prepares and maintains the 'master cost plan' and the 'master programme', and sanctions the building brief. Then, the design team converts the building brief into drawings and specifications, and obtains the detailed planning permission, while the client's representative continues to monitors the design process and agrees the 'forecast tender price'. At the end of the stage, the design is sanctioned by the client's representative.

(4). Tender documentation and tendering: The design leader and the client's representative work together to prepare tender documents, and invite contractors for tender. This stage is completed with a tender being accepted and a contract entered.

(5). Construction: The contractor completes the design which provides co-ordinated working drawings, and carries out work, while the client's representative administers the building contract, approves payments to the contractor, decides on the need for variations and issues instruction. The services of the design leader may be retained during the construction stage, and a supervisor is appointed to monitor the construction work.

The BPF system has similar advantages to the project management system concerning with quality improvement of the project. The role of the Client's Representative is very much similar to that of the Project Manager. The appointment of the Design Leader enhances the co-ordination of the design and provides better design control. The work of the Client's Representative and Design Leader improve the interface control between design and construction.

General procurement process of fire safety engineering

Detailed procurement procedures for fire safety engineering vary with the types of building procurement systems adopted, as it is discussed above. However, it is possible to generalise the process into the following stages:

(1). Fire safety requirements are specified in the building brief.

(2). The concept design of the total fire safety system, i.e. the overall fire safety engineering in the building, is completed before the individual sub-systems are designed and installed. Fire safety specialists may be employed or consulted at this stage in some complex buildings.

(3). Fire safety sub-systems are designed, installed and commissioned by specialised sub-contractors. Each fire safety sub-system is procured individually. Co-ordination among sub-contractors for different sub-systems are made in various ways.

(4). To each fire safety sub-system, the procurement process can be generalised as design and specification, procurement of components and materials, installation, and commissioning.

(5). While each of these sub-systems is commissioned and completed separately, they are brought together at the final stage of the construction. Fire safety sub-systems are interrelated to each others and to some other parts of the building. To assure the co-operation of the total system, commissioning is carried out to co-ordinate the sub-systems. This can be referred as 'total commissioning'.

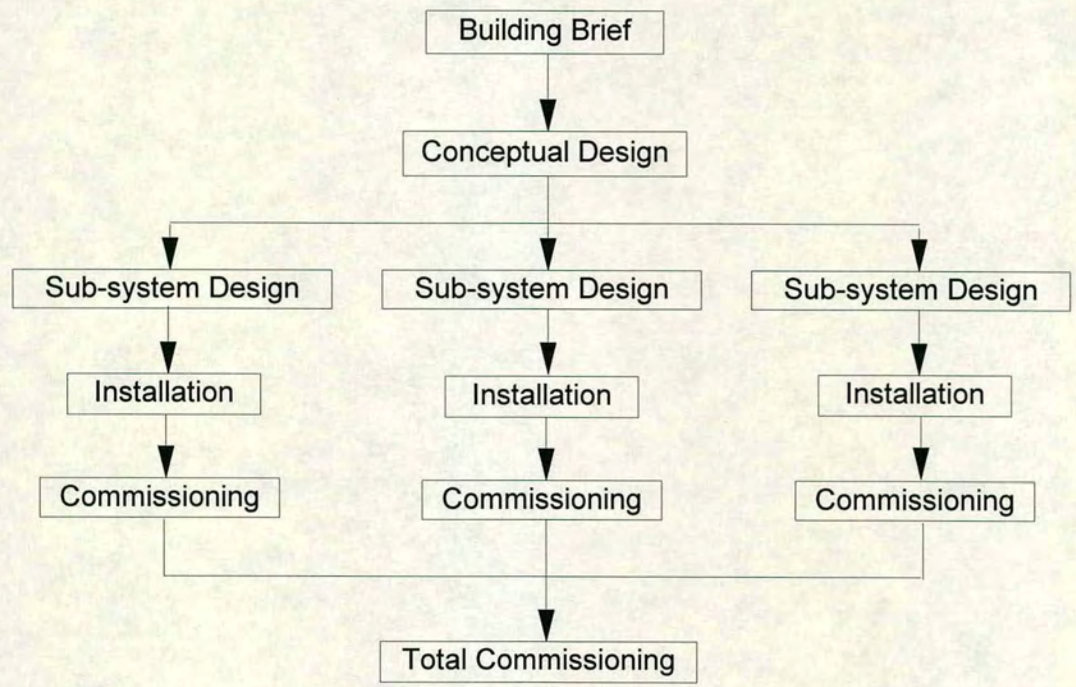

Figure 6.1 Procurement Process of a Fire Safety System

An illustration of the process is shown in Figure 6.1. It provides a general view of the management process of the fire safety engineering packages in building projects and, thus, enables the framework for quality assurance to be developed upon it.

6.3 Quality assurance of fire safety systems: a systematic framework

The features and characteristics of fire safety engineering require that special consideration should be taken while quality assurance is to be applied to fire safety engineering. It is difficult, and is not the purpose of this thesis, to develop detailed formats of quality procedures for each specific form of procurement of fire safety packages. However, it is necessary to develop a systematic framework to provide general guidance for managing quality of fire safety engineering in building projects.

6.3.1 The Framework

The systematic framework of quality assurance of fire safety engineering in a building project consists of three levels:

1. An overall quality plan for the fire safety system, which can be named as 'The Total System Quality Plan';

2. A set of quality plans for fire safety sub-systems, which can be named as 'The Sub-system Quality Plans(s)'; and

3. Quality management systems in fire safety engineering companies.

The quality plans specify the requirements to fire safety systems and sub-systems, define the responsibilities of the contractors, sub-contractors, as well as of individual project team members, and describe quality operational procedures in details. The quality plans are developed at different stages in the project processes, and implemented throughout the processes.

A prominent feature of this approach is to treat the fire safety system as an integrated package in the building project, and the Total System Quality Plan is developed upon the integrated package. The Total System Quality Plan specifies the overall requirements to the total fire safety system, and ensures that effective measures are taken to assure the co-ordinations among individual sub-systems.

However, the complexity of the fire safety system and its procurement process makes it impracticable to set up all the detailed quality requirements and managerial procedures in only one quality plan. Therefore, a set of quality plans are developed for each individual fire safety sub-systems accordingly. While the Total System Quality Plan overlooks the organisation and management of the total fire safety system, the Sub-system Quality Plans specify the detailed quality requirements and operational procedures for individual fire safety sub-systems.

Another feature of the approach is that quality planning is carried out at different stages during the building process. There are two major stages:

Stage 1: Total Planning, which develops the Total System Quality Plan. It should start as early as the building briefing is prepared so that activities of Concept Design can be covered (Figure 6.1). The Total System Quality

Plan should be reviewed and evolved as the project progresses.

Stage 2: Sub-Planning: which develops the Sub-system Quality Plans. Quality requirements to each fire safety sub-system should be defined in the tender documents. Once a sub-contractor enters into the contract, a Sub-system Quality Plan should be developed before the work is started.

Division of these stages will vary according to how the building project management is arranged. They may also be overlapped -- the Sub-Planning may start before the Total Planning has completed. All the quality plans should be reviewed and revised at appropriate stages of the project, and be coherent with the management systems and quality plans of the overall building projects.

Figure 6.2 gives an illustration of the framework of the approach. It is suggested that the client appoints a 'Client's Representative of Quality' to overlook the whole quality issues of the project on behalf of the clients. It is preferable that the 'Client's Representative of Quality' is an employee of the client, or a quality consultant, who is independent from other duties in the project teams, while he may also be the project manager, architect, quantity surveyor or other members of the project management team, or the 'Client's Representative' in the BPF system. No matter what other role he may play in the project, it must defined clearly that he takes the full responsibility for quality management of the project.

It is unlikely to be practical for the 'client's representative of quality' to actually draw up all the quality plans on his own. Neither is it practicable for him to be responsible for every defect of the work which are done by sub-contractors. However, it is his

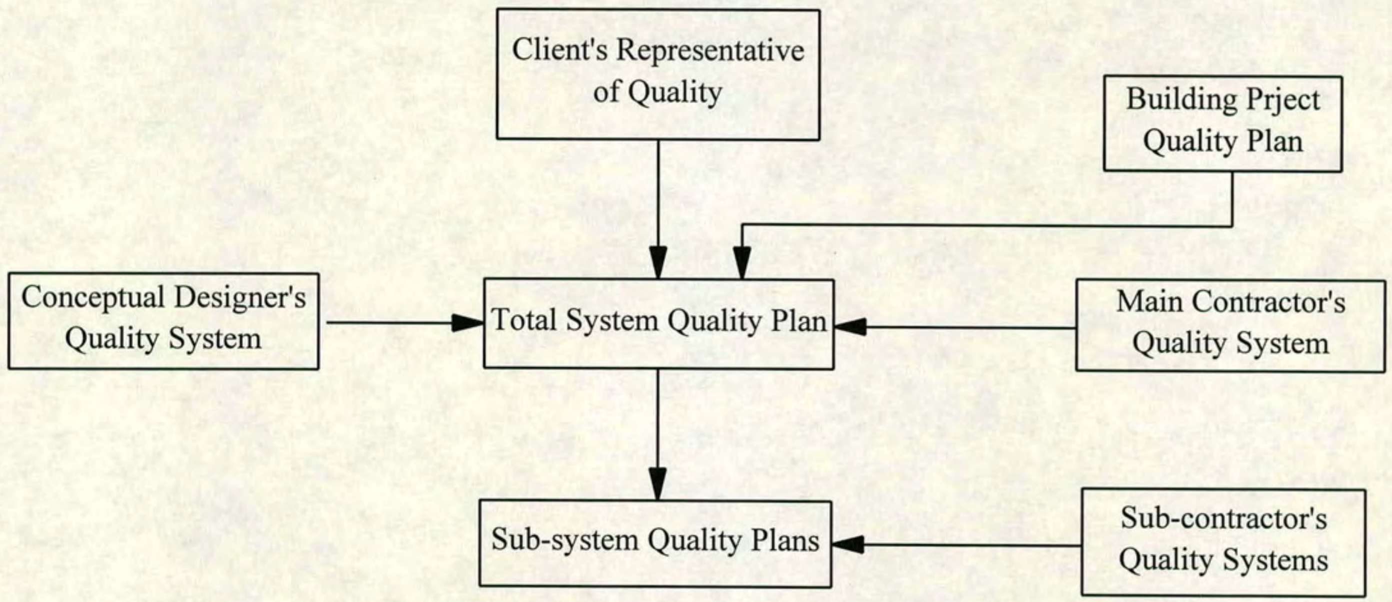

Figure 6.2 Framework of a Systematic Approach to Quality Assurance of Fire Safety Systems

responsibility to develop and review the Total System Quality Plan, and to organise and monitor its implementation. If he himself is not a quality management expert, he must ensure that the quality plans have been developed in a proper way by qualified persons or consulting organisations and are implemented properly. It is also his responsibility to organise and co-ordinate the Total Planning and the Sub-Planning, and to supervise the implementation of the quality plans.

Quality systems in fire safety engineering companies are fundamentals of quality assurance in any fire safety engineering projects. They are essential support to the development and operation of the quality plans in the projects. The quality systems formalise the quality management practices in these companies, and promote quality awareness among their employees. The on-site quality plans have to be coherent with the operation of the quality systems in the companies. BS5750/ISO9000 provides the framework for the quality systems. However, modifications are needed in order to fit the systems with the operation of the fire safety engineering companies.

6.3.2 The Total System Quality Plan

The Total System Quality Plan is the overall quality plan for the total fire safety system in a project. It sets up the framework of quality assurance for the whole fire safety system and the quality procedures for concept design in particular.

The Total System Quality Plan should be developed in parts, and be evolved over the progress of the project.

Parts of the Total System Quality Plan should be issued while the concept design starts, and be implemented throughout the design process. These parts outline the quality requirements to concept design, define the quality responsibilities of the system concept designer(s), specify the operational procedures concerned with quality assurance of the design activities. Other parts of the Total System Quality Plan, which are concerned with the organisation and co-ordination of fire safety sub-systems, may be developed during the concept design, but can only be completed after the concept design is finished.

A typical Total System Quality Plan should include the following aspects:

(1). The overall quality objective to be attained.

The total performance requirements of the fire safety system should be specified. The requirements on other quality dimensions should also be clearly defined. These quality dimensions include reliability, durability, maintainability, economics and aesthetics.

(2). Methods and time schedules for developing and reviewing the Total System Quality Plan.

Since the Total System Quality Plan is developed in parts and evolved over the progress of the project, there should be a special part in the Quality Plan to define the methods and time schedules for developing and reviewing the Plan.

(3). Quality assurance requirements for the System Concept Designer.

The System Concept Designer is the person, or organisation, or a group of people that is responsible for the concept design of the fire safety system. The quality assurance requirements to the System Concept Designer include the requirements to the designer's in-house quality management practice, e.g., a quality system complying with BS5750, and the requirements to the designer's competence.

(4). Allocation of quality responsibility and authority during the concept design.

Responsibility and authority of the designer(s) should be defined clearly in the Total System Quality Plan. While the design is carried out by a design team, it is essential to specify and allocate the responsibilities and authorities among the team members.

(5). Specific quality control procedures and methods to be applied in concept design.

Quality control for the concept design should aim at the elimination of human errors in the design process. The Total System Quality Plan should define detailed procedures for contract review, design control, drawings and documents control.

(6). Quality procedures for communication between the concept designer and other parties.

Effective means of communication should be defined and maintained among the concept designer and other parties in the project. These parties include the architect, the structural engineer, fire safety sub-systems designers and installers, building services sub-contractors, and other relevant specialists and workers.

(7). Organisation of work packages for procurement of fire safety sub-systems.

While the concept design has outlined the structure of the fire safety system, work packages are organised to procure fire safety sub-systems. Organisation of the work packages should be described in the Total System Quality Plan. Organisation charts should be developed, and responsibilities and authorities for managing tenders and contracts should be specified and allocated.

(8). Quality assurance requirements for fire safety sub-systems designers and installers.

These include the requirements to the in-house quality management practices of sub-systems designers and installers. It is now becoming common that fire safety sub-systems designers and installers are required to possess the BS5750 quality systems which have been certified by authoritative certification bodies.

(9). Methods and time schedules on which the Sub-system Quality Plans are to be developed.

Sub-system Quality Plans are to be developed for each work package of fire safety sub-systems. Organisation of these work packages is largely influenced by the building procurement system that is adopted in the project. In different procurement systems, specialised fire safety sub-systems contractors enter into contracts with different parties who can be the client, architect, main builder, management contractor, or project manager. They are also brought into the project at different stages. Individual Sub-system Quality Plans are likely to be developed independently and at different time. It should be defined in the Total System Quality Plan that how and when each of the Sub-system Quality Plans is to developed, and how they are to be co-ordinated.

(10). Quality procedures for control and co-ordination of the interfaces between different fire safety sub-system contractors.

Detailed procedures for interface control and co-ordination should be defined according to the organisation and contractual arrangement of the work packages of fire safety sub-systems.

(11). Quality procedures for total system commissioning.

While some of the fire safety sub-systems are commissioned individually, it is necessary to carry out a commissioning for the total fire safety system to ensure that co-operation of all sub-systems have been achieved. Quality procedures should be defined to guide the total commissioning and to assure quality of the commissioning work.

(12). Procedures and schedules for auditing the Total System Quality Plan.

Quality audits should be carried out throughout the design and construction process to verify whether quality activities comply with the Quality Plan. Audit procedures and time schedule need to be specified, and procedures for feedback of the audit results and corrective actions be defined.

(13). Quality procedures for maintaining quality records.

Quality records are documentary records that are produced through the operation of the quality assurance. Procedures should be specified for identification, collection, indexing, filing, storage, maintenance and disposition of such records.

(14). Other necessary measures.

Any other necessary measures which have not listed above should be specified according to the features and characteristics of the project.

6.3.3 The Sub-systems Quality Plans

The Sub-system Quality Plans are a set of quality plans for individual work packages of fire safety sub-systems. The concept design outlines the structure of the fire safety system, and work packages of fire safety sub-systems are organised accordingly. Every work package of these fire safety sub-systems should have a detailed quality plan.

The Sub-system Quality Plans should be developed on a project basis rather than a sub-contractor basis, especially when the design and installation of the sub-system involves more than one sub-contractors. This can provide better interface control and improve co-ordination among team members.

Development of the Sub-system Quality Plans should follow the guidance that is given in the Total System Quality Plan. Each Sub-system Quality Plan is likely to be developed and implemented independently, but co-operations and co-ordinations must be emphasised. Quality procedures should be specified for communication and co-ordination among all parties and members of the project team throughout design, installation, and commissioning of the fire safety sub-systems.

A typical Sub-system Quality Plan should include the following aspects:

(1). Specification of quality requirements to the fire safety sub-system.

Specification of the quality requirements should cover all quality dimensions such as performance, reliability, durability, maintainability, economy, and aesthetics; and be made as clear and elaborate as possible to avoid any variance in understanding.

(2). Quality procedures for sub-system design.

These procedures involve allocation of responsibilities and authorities in the design activities, including contract review, design control, drawings and document control.

(3). Quality procedures and work instructions for installation of the sub-system.

Responsibility and authorities that are related to installation should be defined and allocated, procedures for controlling the installation process be specified. Interface between design and installation must be controlled. Elaborate work instructions may be not included in the Quality Plan, but requirements and guidance should be provided for the work instructions.

(4). Quality procedures for procuring components and materials.

Quality procedures should be taken to ensure that all the components and materials are procured in accordance with specifications.

(5). Quality procedures for handling and storage of components and materials on site.

These include procedures for receipt, identification and inspection of components and materials delivered to the building site, and handling and storage of them in accordance with the manufacturer's recommendations to ensure protection from damage or deterioration.

(6). Quality procedures for inspection and testing, non-conformance control and corrective actions of installation works.

Verification of compliance with specifications are carried out at three stages: on receipt of components and materials, during installation, and at completion. Procedures for the verification and documentation of the verifying work should be specified. Quality procedures should also be included for: control, calibration and maintenance of inspection, measuring and test equipment; prevention of non-conformance being incorporated into the work; corrective actions for non-conforming work.

(7). Quality procedures for the sub-system commissioning.

Where appropriate, it should be included in the quality procedures the allocation of quality responsibilities for commissioning. Means of process control and interfaces control should be provided. Availability and quality of all the technical documents needed, such as detailed specification, and installation drawings 'as installed' are important for the interfaces control. Detailed commissioning programmes and work instructions may be not included in the Quality Plan, but requirements to these documents should be specified.

(8). Procedures and schedules for reviewing the Quality Plan.

The procurement process of a fire safety sub-system covers design, installation, and commissioning. Variations may occur during the process. It is necessary to establish procedures for review of the Quality Plan at certain stages.

(9). Procedures and schedules for quality audits.

Quality audits should be carried out throughout the design, installation, and commissioning process to verify whether quality activities comply with the Quality Plan.

Quality audit procedures and time schedule need to be specified, and procedures for feedback of the audit results and corrective actions be defined.

(10). Other necessary measures.

Any other necessary measures which have not listed above should be specified according to the features and characteristics of the project.

6.3.4 Quality systems in fire safety engineering companies

The effective application of quality systems in fire safety engineering companies is the fundamental part of quality assurance in fire safety engineering.

Fire safety engineering companies include two categories: a manufacturing sector where companies manufacture and supply components and materials of fire safety systems; and a construction sector where companies supply services for design, installation, commissioning, and maintenance of fire safety systems and sub-systems. Effectiveness of quality systems in these companies is essential to quality of fire safety engineering. As the BS5750/ISO9000 Quality Systems aims to provide general guidance for a broad range of companies, some particular areas need to be emphasised and modified to best fit in with the fire safety engineering companies.

In the manufacturing sector, fire safety engineering companies need to take special consideration to the following aspects:

Design control: While design activities are carried out to develop new products or to modify an existing type of products under a special contract, the designers should recognise the relevant standards, codes of practice, specifications, regulations and statutory requirements applicable to the customer's requirements. Any deviation from the requirements should be formally agreed with the appropriate authority prior to inclusion in the design.

Installation: The companies should provide adequate documented instructions for the correct installation of the components and materials, and provide specialised installation facilities if required by the customers.

Service Support: The companies should provide maintenance, calibration and testing, spare parts supply and technical advice facilities if required by the customers.

Corrective Action: The corrective action procedures should be included in the quality system for dealing with customer complaints. Where appropriate, corrective action should include the recall of suspect material or notification to the customer that the supplied products are suspect.

Records: The records required by BS5750/ISO9000 should be retained for a specified minimum period of time. Specification of the minimum time depends on individual types of products.

Delivery: While required by the customers, the companies should supply a Certificate of Conformity that confirms the conformity of the supplied products to the relevant specification(s) and any other requirements.

In the construction sector, fire safety engineering companies are involved in design, installation, commissioning and maintaining fire safety systems and sub-systems. Business activities of these companies are rather different from those in the manufacturing sector.

Typical companies of this kind include sprinkler installers and fire alarm system installing companies. To these companies, requirements supplemental to the BS5750/ISO9000 Quality Systems are needed in the following areas:

Organisation: Responsibility and authority for quality should be defined and allocated. An organisation chart should be produced clearly identifying the organisational structure and the lines of communication between head office, subsidiary offices, and site.

Record: Procedures for documenting and retaining quality records required by BS5750 should be defined. A minimum period of time for which the records are retained should be specified according to the nature of the products or services, or by the requirements of contracts.

Quality planning: Quality planning should be carried out for each contracted work. Quality planning is based on individual projects and contracts, as discussed earlier in Section 6.3 & 6.4 of this Chapter. The company should appoint a person to be responsible for the implementation of the quality plan.

Design control: Designs of the fire safety system and sub-systems should recognise the relevant standards, codes of practice, specifications, regulations and statutory requirements applicable to the customer's requirements. Any deviation from the requirements should be formally agreed with the appropriate authority prior to inclusion in the design. Procedures should defined to control the design process. Details of parties to be consulted or informed during the stages of preparation of the designs should be kept.

Work instruction and schedule for installation: Clear and precise documented installation instructions should be issued together with the installation design drawings. Relevant quality control requirements are included in the instructions. While required by the client, the company should provide estimated time schedule for completion of the work.

Commissioning: Documented procedures should be defined for the commissioning of installations. These procedures must ensure that commissioning is carried out in accordance with the relevant quality standards and any specific requirements of the client. They should give details of the test routines, results and conclusions.

Control of non-conformance and corrective action: Materials and works that are found during installation or commissioning to be faulty or requiring remedial action should be appropriately identified. Corrective action procedures should provide for dealing with such non-conformance.

Training: All jobs that require specific skills should be identified and documented. Employees for the specific jobs should demonstrate their competence, and when necessary, be trained by the company.

Sub-contracting: When sub-contractors or sub-contracted labour are employed, quality responsibility should be clearly defined and allocated. Procedures should be specified for dealing with procuring and monitoring sub-contracted works.

Complaints: A documented procedure should be included for dealing with all complaints. Full details of each complaint must be obtained and investigated, details of any action be recorded before and after being taken.

In summary, quality assurance of fire safety engineering in building project has its characteristics. The systematic approach for assuring quality of fire safety systems should involve quality planning for the project and in-house quality assurance in the fire safety engineering companies. Quality planning should be carried out in stages and in accordance to the organisation of the work packages of the project. It must be point out that the issue of co-ordination between separate work packages needs to be stressed, and an more integrated and systematic way of planning for quality needs to be developed in the future practice.

Chapter 7 Quality Assurance in Fire Safety Engineering Firms

The effectiveness of quality assurance in fire safety engineering firms is vital to the achievement of quality of fire safety engineering projects. It is suggested that the implementation of quality assurance programmes is a process of organisational change. This chapter explores the organisation change process, examines the causes and effects of quality assurance in fire safety engineering firms, and investigates the factors that influence the development and implementation of the quality systems in these firms.

7.1 Introduction and background

Quality assurance has been introduced into the fire protection industry in recent years with adoption of the BS5750/ISO Quality Systems in fire safety engineering firms. There is a need to examine the causes and effects of the quality assurance programmes, and to investigate the factors that influence the development and implementation of the quality systems in these firms.

7.1.1 Methodology

The fire protection industry is a very complicated industrial sector, which involves many engineering disciplines. Some special features of the fire protection industry affect the development and implementation of quality assurance in many ways, both positively and negatively.

To some extent it is difficult to investigate the technological issues of the application of quality assurance in all sectors of the fire protection industry in great detail because of the great diversity of the fire safety engineering firms and the complex structure of the industry itself. However, it is meaningful to examine some general features of quality assurance in regard to the whole industry and to make some comparative studies between different types of fire safety engineering firms. With this purpose, a series of interviews and a questionnaire survey have been conducted in a number of fire safety engineering firms which have introduced quality systems and have obtained quality assurance certificates.

The fieldwork for this part of research was carried out at three phrases:

(1). Case studies were carried out in 9 fire safety engineering firms. Visits were made to these firms and interviews were conducted with various personnel. Formal and informal observations were made throughout the visits. Relevant company documents such as Quality Manuals and Quality Procedures were studied.

(2). A questionnaire survey was carried out to 88 fire safety engineering firms. 56 valid responses were obtained, which formed a set of quantitative data for the research. Statistical methods were used for analysing the data. The Statistical Package for Social Science (SPSS) was employed. It must be pointed out that, because of the relatively small sample size and large diversity of some variables, also because of the possible bias that might be caused by nonresponse (Tull and Hawkins, 1990), the analyses and interpretation of the data were carried out with caution. The results are presented in a descriptive way to reveal the trends inherent in the responses.

The reasons for nonresponse were estimated as: (1) The nonresponding companies were too busy to respond to the survey; (2) The nonresponding companies were not as interested in quality assurance as the responding companies. Unfortunately, these estimates were difficult to be tested since there was no way to contact the nonresponding companies. It is hoped that the nonresponse error would be limited as the data was used to describe the trends of the response rather than to make conclusion of statistical significance about the whole population.

(3). 5 case studies were carried out in fire companies who responded to the questionnaire survey. The purpose of these case studies were to seek deeper understanding and explanation of the facts and trends revealed from the questionnaire survey, and to collect more necessary data that had not obtained through the previous case studies and the questionnaire survey.

While this part of the work studied into the quality assurance matters in fire safety engineering firms, a focus was put on the organisational change that took place through the operation of the quality assurance programmes in these companies. The organisational behavioural aspect of quality assurance was explored, attempted to contribute to both the understanding of quality assurance in fire safety engineering and the development of the theory of quality assurance.

7.1.2 Diversity in Fire Safety Engineering Firms

Although the fire protection industry is only a small and emerging industrial sector within the construction industry, the structure of the industry is rather complicated. This is mainly because of the industrial traditions and the complex nature of fire safety engineering. The complexity of the industrial structure is reflected in the great diversity of the fire safety engineering firms. The diversity of these firms is characterised in the following three aspects:

(1) Large firms and small firms

Fire safety engineering firms vary greatly in their sizes. Of the 56 companies surveyed, 11 companies have numbers of employees below 30 and annual turnover less than £2m, while 2 companies have employed more than 100 people with annual turnover of more than £50m. Tables 7.1 (a) and (b) show the distribution of numbers of employees and the annual turnover of the 56 companies.

Although this distribution is not likely to represent the actual proportion of company sizes of all the fire safety engineering firms, it reveals the fact that the diversity does exist. Research shows that business strategy and management techniques to be employed by a company can be influenced largely by the size of the company. 'Small firms' have been recognised as a specified category of businesses which need special concern over their development and management(Bolton, 1971; Norris, 1984).

(2). Discrete Business Areas

Fire safety engineering is a composite application of knowledge and expertise from various engineering disciplines. Because of the very nature of fire safety engineering, and also partly because of industrial traditions, fire safety engineering firms are grouped under a range of specialised business areas such as fire extinguishing equipment and systems, fire detection and alarm equipment and systems, smoke control facilities, fire resistant building components, and other products and services. Many of these industrial groups are in fact distinctive industry sub-sectors with their own specialised industrial organisations and trade associations. Only a small number of large firms are involved in several business areas within the several parts of fire safety engineering.

Table 7.1 Size distribution of the surveyed companies

(a). Number of Employees

NUMBER OF EMPLOYEES	NUMBER OF FIRMS
UNDER 10	3
10~29	10
30~49	10
50~99	12
100+	21
Total	56

(b). Turnover (in 1992)

TURNOVER	NUMBER OF FIRMS
UNDER £1m	2
£1~2m	12
£2~5m	14
£5~10m	5
£10~50m	17
£50m+	2
MISSING	4
Total	56

Each of these industry sectors has its own client base and market environment, its specific requirements of products and services, and different traditions and codes of business practice. These characteristics will influence the development and implementation of the quality assurance in the specific industry sector, as it is shown by the research results which will be presented later in the Chapter.

(3). Manufacture versus Installation

Fire safety engineering firms can be categorised into two major groups: the manufacturing companies and the installation companies. Manufacturing companies are involved in the fabrication of fire protection equipment and its components, while installation companies undertake design, installation and maintenance of fire safety engineering systems in buildings. Beyond these two groups, there are only a small number of large firms which are involved in both manufacture and installation of the fire safety systems. The survey results reveal different experiences of manufacturers and installers of fire safety systems in their quality assurance activities. A detailed discussion on this issue is made in Section 7.5 under the sub-title of 'Business Activities'.

7.1.3 Quality assurance programmes and some general information

One of the purposes of the survey is to obtain some general information about the 'Quality Assurance Programmes' in fire safety engineering firms, such as 'How many months or years did it take the companies to prepare their quality assurance systems?' 'What experience had they had in quality management before the quality systems were introduced?' 'Whether or not did they feel pressure from outside their organisations at the time they decided to introduce quality systems?'

A quality assurance programme, whether it is so named or not, is usually launched when the company has decided to introduce the quality system into its organisation. The programme is usually divided into two stages: (1) the preparation stage, and (2) implementation stage, although these stages may not be distinguished by the management of the companies.

(1). The preparation stage commences when the decision is made that the company is to install a quality assurance system, and is completed when a quality certificate is obtained. It involves establishing the quality system, training staff, the initial operation of the system, registering with a certification scheme, and other related matters.

(2). The implementation stage commences after the company has received the quality certificate. In this stage the quality system is put into formal operation under regular surveillance of the certification organisation; new quality procedures are customised; and any changes caused by the new system are internalised. The length of this stage depends on many organisational characteristics of the company. The company may consolidate the quality assurance programme with other quality improvement programmes and progress to a higher level of quality management.

The survey shows that, of the valid 44 responses, 50% of them spent less than one year on preparation stage, while another 43.2% spent more than one but less than two years. Among all the 56 surveyed firms, 24 (42.8%) of them have achieved quality system certificates for less than two years, while 19 (33.9%) firms have held their certificates for more than 3 years.

Other information revealed by the survey includes the following:

(a). Among the 56 surveyed companies, only 26 companies had some quality procedures similar to the requirements of BS5750 before they formally adopted the quality systems. The remaining 30 firms had no previous quality procedures of this kind.

(b). 42 companies claimed that they felt pressure from outside the company demanding quality assurance. Of the organisations and groups which created this pressure, certification bodies and clients are the most persuasive ones, while business rivals have also had considerable impact. Detailed discussions follow in the next section.

(c). 24 of the 56 companies are registered with more than one certification body. Most of the companies are registered with the Loss Prevention Certification Board (LPCB) and the Quality Assurance Services of the British Standards Institution (BSI/QAS).

7.2 Reasons for adopting quality assurance

The reason for fire safety engineering firms introducing quality assurance into their companies is investigated in the research. The major motivators which cause a company to start its quality assurance programme are identified as: (1) client's need; (2) market competition; (3) development of certification schemes; and (4) the company's business development strategy.

(1). *Client's need*: The demand from clients is the most important driving force for quality assurance. Quality is about meeting the customer's or client's requirement. The highly competitive market provides clients with a wide range of options. Quality has become an important factor that influences client's choices of the products or services they need. Quality assurance is regarded by clients as evidence of the supplier's achievement of quality management and, therefore, gives them confidence to procure from that supplier. Fire safety engineering firms are increasingly under pressure from their clients who demand quality assurance. In the survey, 31 out of the 56 companies claimed that they frequently received enquiries from clients in regard to their company's quality assurance status and quality management practice.

(2). *Market competition*: Market competition is another important motivator of quality assurance. The effect that market competition has on quality assurance results from two facts; that clients are always demanding, or rather, preferring better quality; and that business rivals are improving their performance in quality management. While the client's preference of better quality products or services provides the base for competition, the conduct and performance of business rivals set the competition rules. When business rivals have advertised their achievement of quality assurance, the company would almost certainly feel that it would lose competition if it failed to attain the same quality certificate. The survey shows that a considerable number of fire safety engineering firms felt pressure not only from their clients but also from their business rivals (See Table 7.2).

(3). *Certification schemes*: A notable finding of the survey was that it revealed that the certification body plays an important role in the promotion of quality assurance within the fire protection industry. The survey result shows that the certification bodies has produced a significant pressure for quality assurance on the fire safety engineering firms involved in the survey.

Certification bodies are the medium through which quality assurance is accomplished. The quality certificate issued for a product or a service under a certification scheme is regarded by customers and clients as the evidence of quality. A certification scheme interprets customer's requirements into its technical criteria on which the suppliers' quality systems as well as their products or services are assessed. Based on the recognition from both customers and suppliers, certification bodies acquire the power for promoting quality assurance by establishing new certification schemes and revising the criteria in current schemes. Any change in a certification scheme can cause substantial effects in quality assurance practice within the industrial area it covers. In such a recent event, the Loss Prevention Certification Board (LPCB), an authoritative certification body in the fire protection industry, replaced its traditional quality approval schemes with its new quality certification schemes under which the quality system is a compulsory requirement. This new policy has had a great impact on promoting quality assurance in fire safety engineering firms. In a series of interviews supplemental to the questionnaire survey, a number of quality managers suggested that their companies would not have developed their quality systems had it not been required by the LPCB's new certification scheme (See Appendices 3~16).

Apart from certification bodies, clients, and business rivals, other organisations also have some influence on the development of quality assurance in fire safety engineering firms. Table 7.2 presents a summary of these organisations.

(4). *Business development strategy*: External pressure is, undoubtedly, the important driving force for quality assurance. However, it is not the only driving force. Whilst 42 of the 56 surveyed companies felt pressure from outside their organisations, at the time they developed their quality systems, the other 12 companies claimed that they did not feel any such pressure. The major reason for them introducing quality assurance systems was their awareness of the need for quality assurance among their potential clients in the future market. Seeking future business development and attaining leadership in the future market, these companies adopted a strategic approach to introduce their quality assurance systems. Not only to secure the existing market by satisfying current demand but also to meet the future demands of quality assurance as a vehicle to pursue long-term profit.

Table 7.2 Responses to organisations from which the companies felt pressure

	Count	Percentage
CERTIFICATION BODY	29	69.0
CLIENTS	24	57.1
BUSINESS RIVALS	14	33.3
GOVERNMENT	10	23.8
FIRE AUTHORITIES	10	23.8
INSURERS	9	21.4
TRADE ASSOCIATIONS	9	21.4
BUILDING AUTHORITIES	7	16.7
FIRE PROFESSIONAL INSTITUTES	4	9.5
Valid cases	42	

7.3 Benefits and drawbacks of quality assurance

Advantages and disadvantages of quality assurance in construction industry have been widely discussed by numerous writers, for example, Hughes and Williams (1991), Griffith (1990), Ashford (1989), and Duncan et al (1990). Reports on effects of quality assurance in some companies have been seen now and then in various publications. However, most of these writings are based on rationale or experience of individual cases. Up to end of 1992, the period when the survey was carried out for this work, few surveys had been reported that were carried out in a certain scale to examine the effects of quality assurance. In 1993, CIRIA did a survey of this kind within the construction industry in the UK but has not published the findings for some reasons. It is speculated that the survey results would to some extent be negative and controversial (Billingham and Stewart, 1993).

In the fire industry, little research had been done, prior to present research, to evaluate the effectiveness of quality assurance in the industry. It was revealed from the survey that application of quality assurance has benefited the fire safety engineering firms in general. The main benefits that the companies have experienced from the use of quality systems include:

- formalising work procedures,
- improving traceability of work,
- improving communication,
- improving organisation efficiency,
- improving quality,
- reducing error and mistakes, and
- improving marketing competitiveness.

More than 90% companies indicate that the quality assurance formalises their work procedures, and more than 70% companies say that it improves traceability of the work. These suggest that 'formalising work procedures' and 'improving traceability' are the most popular benefits that have been experienced by these companies. However, less than 50% of the companies indicated that quality assurance improved their marketing competitiveness.

The survey results also indicate that some companies have gained more advantages than others. A few companies claimed that they have not seen any of the benefits listed above.

A major drawback to quality assurance which has been experienced by majority of the companies is that it increases work burdens. An increasing financial burden is regarded as another major drawback by many companies.

Nearly 80 percent of companies believe that quality assurance is cost-effective or will be so in a long term. The remaining 20 percent of companies either think that quality assurance is not cost-effective at all or state that they are not sure about it at the moment.

Table 7.3 gives a summary of the survey results.

Table 7.3 Benefits, Drawbacks and Cost-effective

(a). Benefits

BENEFIT	Count	Percentage
COMMUNICATION	30	53.6
WORK PROCEDURES	52	92.9
EFFICIENCY	31	55.4
COMPETITIVENESS	26	46.4
TRACEABILITY	40	71.4
QUALITY	36	64.3
REDUCE ERROR	34	60.7
OTHERS	4	7.1
NOT YET SEEN	1	1.8

Valid cases 56; missing cases 0

(b). Drawbacks

DRAWBACK	Count	Percentage
FINANCIAL BURDEN	29	54.7
WORK BURDEN	40	75.5
BUREAUCRACY	13	24.5
NOT YET SEEN	6	11.3

Valid cases 53; missing cases 3

(c). Cost-effective

COST-EFFECT	Count	Percentage
YES	35	62.5
NO	6	10.7
LONG TERM	9	16.1
NOT SURE	6	10.7

Valid cases 56 Missing cases 0

7.4 Quality assurance as a process of organisation change

Organisation change is to change the pattern of recurring behaviour of the organisation members. It involves a set of activities and processes that are design to change individuals, groups and organisation structures and processes.

It was revealed by the case studies that were carried out in the 14 companies (Appendices 3~16) that the implementation of the quality assurance programme was a process of planned organisational change. When quality assurance was implemented in these companies, it required a series of changes to be accomplished within the companies. Concluded from the experience of the 14 companies studied, the required changes involve the aspects of organisational structure, behaviour patterns of individuals and groups, work attitudes, and corporate culture. The objectives of the organisation change include: (1) establishment of the quality organisation, namely, the formal quality system; (2) change of attitudes to quality and quality assurance; (3) achievement of quality commitment at all levels of the organisation, and (4) creation of a quality-orientated corporate culture.

Establishment of the quality organisation: Quality assurance in the companies that involved in the research were started with the establishment of a formal quality system. It is stated in BS5750/ISO9000 Quality Systems: 'In order to meet its objects, the company should organise itself in such a way that the technical, administrative and human factors affecting the quality of its products and services will be under control.' This means that a company should select an appropriate structure of the quality system which best fits the company's production activity and its existing

Organisational structure. A number of guidance to quality systems have been provided in BS5750/ISO9000 and other supplemental documents published by various certification bodies. By establishing the quality system, the company defines and allocates responsibilities and authorities to quality, defines clear lines of communication, formalises quality operation procedures, introduces new quality practice, and inputs necessary resources to ensure effective operation of the quality system.

Change of attitudes: Employee's attitudes to work largely affect their job motivation. Positive attitudes to the practice of quality assurance is essential to the achievement of quality. The studies in the fire safety engineering firms indicated that such positive attitudes were not always held by all members of the organisation at early stage of a quality assurance programme. There was a need for attitudes change. Quality awareness was a key factor that contributes to the establishment of a positive quality attitude. It is suggested that this awareness can be achieved through a combination of various measures such as training and education. The importance of quality should be understood by every persons in the company. The effectiveness of a quality system relies on the collective contribution from every individuals in the organisation.

Attitudes change must start from the top management of the company. Management then use their power and other persuasive means to influence and alter employee's attitudes.

Achievement of commitment: It has been widely recognised that a true commitment to quality is the key to the achievement of quality. The effective implementation of the quality system also requires the achievement of commitment to quality at all levels of the company. The top management must ensure that they make true commitment to quality. Such commitment must be communicated to all employees of the company, from middle managers to production line workers. Quality commitment is essential to the achievement of company's quality objectives, especially when an urging order is received, and when maintaining the quality standard demands extra work efforts or sacrifice of some short term profits.

Creation of corporate quality culture: Corporate quality culture refers to the corporate culture in which the achievement of quality is emphasised and has become a part of the core value of the corporate. Successful examples of quality management demonstrate that the corporate quality culture is extremely important to the achievement of quality. To build up such a corporate culture is the most important objective of quality assurance for it lays out the base of employee's positive attitude and motivation to implement the quality assurance procedures and reduce human errors. However, quality culture is also the most difficult objective to be achieved. It involves shifting the company's value system, changing of attitude, setting up new codes of behaviour, etc. It demands time and efforts from the management.

It is suggested that the organisational change process brought about by the implementation of quality assurance follows the change pattern of 'unfreezing, changing, and refreezing' that is proposed by Lewin(1956).

Unfreezing phase: The need for quality assurance is recognised by the management and is communicated to all employees of the company. The quality system is developed and employees are trained for the implementation of the quality system and quality procedures.

Changing phase: The quality system is put into operation, and quality procedures are introduced and implemented formally. With the introduction of the quality procedures, changes take place in many aspects that include operational procedures, attitudes, and corporate cultures. Further training and education are carried out to direct the changes. Internal quality audits are undertaken regularly to motivate and monitor the changes.

Refreezing phase: Operation of the quality system has been incorporated into the total operation of the company. Implementing quality procedures becomes part of the routine work. The real quality commitment has been achieved, and a quality-orientated corporate culture is developed.

Successful accomplishment of the change process is essential to the effectiveness of the quality system. Some factors that affect the change process are identified and discussed in Chapter 7.5. Company management should recognise the change process and the influencing factors according to the situations of their own organisations. Training and education are effective measures to promote changes and must be carried out throughout the change process.

Within the three phases of the process, the changing phase is the subtle one. On one hand, it starts with installation of the quality system, and often ends in certification to the system. On the other hand, it is difficult to identify the changing phase in the aspects of attitudes and corporate culture. Research data indicate that changing of attitudes and corporate culture is a long term task, and is often not completed even after the quality system is certified. This means that the achievement of a quality certificate does not mark the end of the changing process. More effective measures need to be taken to promote and reinforce the change.

7.5 Some factors that affect the effectiveness of quality assurance

Quality assurance is an effective tool to improve quality and organisational efficiency (Griffith, 1990; Duncan et al, 1990). However, it is not a guarantee for success. A quality system sets up the necessary organisational structure and working procedures within a company to ensure that products and services are conforming to client's requirement. However, the effectiveness of quality systems is largely affected by various factors that stem from the business environment of the company and the behaviour of it members. The successful and unsuccessful experience of some companies suggest that quality assurance requires a company not only to establish a quality system but also to accomplish a series of organisational changes that are necessary for the achievement of a commitment to quality. Some factors that affect the accomplishment of the changes and their effects on implementation of quality systems are discussed below.

(1). The gap between different goals

Quality assurance is to provide the evidence needed to establish confidence on quality of supplied products and services. In current practice, quality assurance is built on the mechanism of 'third party certification'. A quality certificate to the supplier's quality system, that is issued by an independent certification bodies, is regarded as the evidence upon which the purchaser's confidence on quality is established. A company starts its quality assurance programme for various reasons such as to meet a client's requirement, to compete with business rivals, to improve the image of the company, or to improve quality of its products and services. The immediate goal of a quality assurance programme, however, is always to obtain a quality certificate which enables the company to gain its client's confidence and therefore to advance its market.

Behind such an immediate goal of obtaining a quality certificate, the purpose of quality assurance is to ensure that all products and services supplied by the company are consistently meeting quality requirement. It is the output of consistent quality that is the final goal of a quality assurance programme. To achieve constant quality, the company should not only develop a capability to deliver quality products and service, but also achieve a full quality commitment from all members of the company. A certificate to the quality system in accordance with the requirement of BS5750 confirms the possession of such a capability. But it hardly proves that the company has achieved a real commitment.

The research results suggest that the acquisition of a quality certificate does not always result in the achievement of such a commitment. In some interviews managers revealed their negative views about the quality systems. They felt that they were forced to have a certified quality system by external pressure such as the certification body (LPCB) and some clients. A quality certificate is important for their companies to develop business. Without such a quality certificate their companies would lose their market shares. However, they see no need for the quality system itself. They do not believe that the quality system will improve either their work or quality. Although such companies possess a quality certificate, they are not likely to have achieved a commitment to the implementation of their quality systems. Nor are they likely to have achieved a full commitment to quality. There remains a gap between the achievement of quality certification and the achievement of quality commitment.

Quality commitment is essential to the effectiveness of a quality system. It is related to quality awareness, motivation, and attitudes of members of the company. A corporate culture that emphasises the value of quality provides necessary environment for the achievement of individual's commitment to quality.

(2). Pre-experience

'Pre-experience' refers to the previous experience that company has in formal quality management before the quality system is established.

It was revealed from the survey that pre-experience had a meaningful effect on the company's attitudes to quality assurance and the benefits they have experienced. Companies with pre-experience tend to have a more positive attitude towards the beneficial effects of quality assurance and see quality systems as more cost-effective than those companies without pre-experience.

Apart from the organisational structure aspect of the quality management which is greatly emphasised in the quality system, the human behaviour aspect of the quality management, which includes awareness, attitude, and commitment, is equally important to quality assurance. Introduction of quality assurance brings changes to various aspects of a company. Less pre-experience usually means that greater changes are required, both to the organisational structure and to the aspects of human behaviour. Organisational change, especially change in human behaviour, is a long term process which needs consistent effort. To companies who have little pre-experience it is essential to promote quality awareness within the whole organisations and to create a quality-oriented corporate culture.

(3). External pressure

External pressure that come from clients, markets, certification schemes, and other sources demanding for quality assurance is an important driving force for the development of quality assurance. It is also an influential factor that affects the effectiveness of the quality system.

The survey result shows that companies that began their quality assurance programmes merely to meet external pressure tend to have some negative attitudes towards quality assurance. On the other hand, companies that developed their quality systems without external pressure, appear to be more positive in their attitude to the effectiveness of quality systems. Among the 14 companies who claimed that they did not feel pressure from outside at the time when they started quality assurance, 11 of them indicated that quality systems have been cost-effective in their companies while the other 3 companies believed that they will be cost-effective in the long term. Companies who indicated that quality systems are not cost-effective all fall into the category of those who developed their quality systems under external pressure.

According to Lippitt et al (1958), organisational change occurs when a new driving-force for change has intruded into the field of change forces and the balance of driving-forces for change and restraining forces against change is broken. External pressure for quality assurance is such a new driving force for change. However, no one likes to change. When people want to change, it is because they see the new behaviour as being their own self-interest. When change is imposed and the members of the organisation cannot see how the change benefits them, they may appear to change in order to test it or show loyalty, but such change is not likely to survive for long. In some companies the introduction of quality assurance are demanded by external pressure, but members including managers of the companies see neither the need of quality nor the benefits of quality assurance. Although the quality system and new quality procedures are established and implemented, they may not be internalised. The goal and motivation of quality assurance in such companies may remain as the possession of a quality certificate. Quality commitment may not be achieved.

(4). Leadership and change agents

The importance of leadership to quality improvement has been stressed by numerous writers such as Crosby (1979), Deming (1982), Mortiboys (1984), Price (1987), Harrington (1986), and Hutchin (1990).

Oakland (1989) points out that, to be successful in promoting business efficiency and effectiveness, quality management must start at the top with the chief executive. While quality improvement brings about organisation changes in the companies, the chief executives work as the essential change agent. (Lascelles and Dale, 1991)

Top management plays a key role in the introduction of quality assurance. Quality systems can be implemented only from the top town. Quality managers are appointed to take responsibility for the implementation of quality systems. Many quality managers are independent from other management duties. However, in some small firms, quality managers are often concurrently the operational managers or other functional managers. In such cases, the quality commitment from the management are even more important to the effectiveness of the quality systems.

Beckhard (1969) defines that 'change agent refers to those people, either inside or outside the organisation, who are providing technical, specialised, or consulting assistance in the management of a change effort'. Ottaway (1979) divides change agents into three categories corresponding to the three phases of Lewin's (1952) change model: 'change generators' ('unfreezers'), 'change implementers' ('changers'), and 'change adopters' ('refreezers'). Lascelles and Dale (1991) criticise that most of the literature on change agents appears to concentrate on the implementation of change rather than the causation or motivation of change. Their definition of a change agent is 'a person (or group of people) who cause change as well as implementing it'. They emphasise the causational role of change agents. In this thesis, change agents refer to people who initiate, assist, and implement changes in the organisational process. It does not include the 'causal factors' of change which are discussed in Chapter 7.2. The survey result indicated that quality managers and managing directors were the most important change agents.

In a few cases, quality assurance consultants played a significant role in some companies. They helped the management of the companies to recognise the need for quality assurance and developed the quality systems for the companies. They also engaged in increasing the quality awareness of the company's employees through running seminars and training courses for the companies. However, in one particular case, quality assurance consultation was proved ineffective. The consultant was employed to develop the quality system for the company. But the quality system was later abandoned because it was not fitted in with the company's established business operation procedures.

At the late stage of the research, investigation were carried out to reveal that how the management, including the managing directors and quality managers, worked as change agents. The research findings are summarised as following:

On the establishment of quality systems, the management set up the company's policy on quality and made a statement to announce the management's commitment to quality. Throughout the quality assurance programmes, the management were to commit themselves to a series of activities of explanation, education, motivation, and persuasion in order to promote changes. In some companies, quality campaigns were organised to create a change climate. Internal quality audits were used by the management as a tool for motivating changes.

(5). Company Size

Company size is a significant factor that influences business strategies and management techniques that are employed by a company. In the context of quality assurance, it is revealed from the survey that there are meaningful differences between larger fire safety engineering firms and small ones.

Larger firms usually have more positive attitudes toward quality assurance. This is because they are more aware of the needs for the quality systems which systematise the company's quality management practice and increase efficiency. In small firms, on the other hand, the ways of communication within the organisations are usually simple and informal. There are less needs for the formal quality systems in these firms. The survey shows that larger firms have obtained more benefits from quality assurance than small firms.

Larger firms possess more pre-experience that small firms. Larger firms often have some quality management procedures before they establish their formal quality systems. Although these procedures may not be as systematic as described in BS5750, they provide employees with concepts of formal control procedures. Few small firms have written quality procedures before quality assurance. Thus, small firms are likely to experience greater change than larger firms while quality systems are introduced.

(6). Business Activities

Major categories of business activities of fire safety engineering firms include manufacturing and installation. For the purpose of comparison, 10 sprinkler installers and 9 manufacturing firms were selected from the surveyed companies. The comparison shows a number of interesting features of their experience in quality assurance practice.

1. Nine out of the ten installers felt an external pressure for quality assurance. Four of these companies felt pressure from the certification body only, due to the revision of the certification scheme. In the manufacturers group, on the other hand, only five of them felt external pressure at the time when they started their quality assurance programme, while the other four companies stated that they introduced the quality assurance system for improving the product quality and for improving their marketing competitiveness in the future.

2. Six manufacturers had some formal quality procedures, similar to the requirements of BS5750, in operation before the formal BS5750 quality systems were introduced. However, only one installer had such quality procedures in place at the time when the formal quality systems were developed in these companies.

3. While client's need and marketing competition are recognised as important reasons for the development of quality assurance, manufacturers and installers are facing different client and market environments. It is interesting to notice that the quality awareness of the clients of manufacturers are higher than that of the clients of installers. Of the nine manufacturers, eight are frequently receiving questionnaires from their clients inquiring about their quality assurance status and quality systems, while six out of the ten installers only receive such questionnaires occasionally and one installer has not yet received any.

4. Manufacturers see more benefits and less drawbacks of quality assurance than the installers do. Table 7.4 (a), (b), (c) are the comparisons of the responses between the two groups to the benefits and drawbacks they have experienced and the cost-effectiveness of their quality assurance activities. The table show a clear difference between them.

In conclusion, these facts reveal that the business activity that a company is involved has a significant influence on the process of organisation change that is brought about by the introduction of quality assurance, and on the effectiveness of the quality systems in short term.

(7). Resistance to change

Quality assurance brings about organisational change. However, organisations are social structures that tend to rationalise and depersonalise their behaviours in order to make them more predictable and efficient. Organisations are not meant to change. Writers such as Hellriegel et al (1986), Organ and Bateman (1986), and Kerr and Kerr (1972) have summarised a number of reasons

TABLE 7.4 COMPARISONS OF RESPONSES BETWEEN INSTALLERS AND MANUFACTURERS

(a). RESPONSES TO BENEFITS

BENEFIT	INSTALLERS Count* Row pct** Col pct***	MANUFACTURERS
COMMUNICATION	3 37.5 30.0	5 62.5 55.6
WORK PROCEDURES	7 43.8 70.0	9 56.3 100.0
EFFICIENCY	3 33.3 30.0	6 66.7 66.7
COMPETITIVENESS	0 .0 .0	8 100.0 88.9
TRACEABILITY	5 41.7 50.0	7 58.3 77.8
QUALITY	1 11.1 10.0	8 88.9 88.9
REDUCE ERROR	3 33.3 30.0	6 66.7 66.7
OTHERS	1 100.0 10.0	0 .0 .0
NOT YET SEEN	1 100.0 10.0	0 .0 .0
Total	10	9

19 valid cases; 0 missing cases

* COUNT: NUMBER OF RESPONDENTS;
** ROW PCT: PERCENTAGE OF RESPONDENTS OF THE TWO GROUPS COMBINED (INSTALLERS AND MANUFACTURERS);
*** COLUMN PCT: PERCENTAGE OF RESPONDENTS AMONG THE SAME GROUP.

(b). RESPONSES TO DRAWBACKS

DRAWBACK	INSTALLERS (Count* / Row pct** / Col pct***)	MANUFACTURERS
FINANCIAL BURDEN	8 72.7 80.0	3 27.3 37.5
WORK BURDEN	9 60.0 90.0	6 40.0 75.0
BUREACRACY	5 83.3 50.0	1 16.7 12.5
NOT YET SEEN	0 .0 .0	2 100.0 25.0
Total	10	8

18 valid cases; 1 missing cases

* COUNT: NUMBER OF RESPONDENTS;
** ROW PCT: PERCENTAGE OF RESPONDENTS OF THE TWO GROUPS COMBINED (INSTALLERS AND MANUFACTURERS);
*** COLUMN PCT: PERCENTAGE OF RESPONDENTS AMONG THE SAME GROUP.

that lead to the resistance to change. As evidenced from the research, the resistance to change related to quality assurance mainly result from the following:

(a).*Lack of awareness of the need for change*: The need for quality assurance have not been truly understood. Members in the company including some top managers may feel that their present system and working procedures are good enough and that the introduction of the new quality assurance procedures will not improve their work but increase work burdens.

(b). *Misunderstanding and lack of trust*: Employees, even top managers of the company, may misunderstand the purpose of quality assurance, or do not really believe that quality assurance brings improved work performance and better quality. Some managers believe that quality assurance is only a tool for marketing and therefore the purpose of quality assurance becomes obtaining and maintaining the quality certificate. Quality procedures and work instructions may not be fully understood and trusted. On several occasions a few quality managers also showed their disagreement with the certification body over some certification criteria and argued that the certification body's requirements are only to put unnecessary work burdens on them.

(c). *Sunk cost*: The term 'sunk cost' is used by Organisational behaviourists to explain resistance to change caused by people's fear of losing their investments in the status quo(Kerr and Kerr, 1972; Filley et al, 1976). People may consider his time and energy that he has spent on learning and mastering a set of operation to be investments. Any loss or reduction in their value may be felt as keenly as if actual money or property were involved. Resistance may be aroused if operations and skills already mastered are threatened to be written off as a result of change. When new quality assurance procedures and work instructions are introduced to replace some old work routes, quality managers can hear this kind of words from some senior personnel: 'What are wrong with our previous ones?' 'I've been working in this way for years. It never goes wrong. Why bother to change it?' 'I've been working on this job for more than twenty years. Now you are telling me how to do it?!'

(d). *Fear of losing security*: Employees fear that their mistakes will be seen if quality assurance procedures are implemented strictly, which may, in their eyes, lead to embarrassment, and threaten their job security and promotion prospects.

(e). *Fear of losing autonomy*: Quality assurance often requires greater inspection and supervision. For example, in some design offices, quality systems introduce a procedure of 'double checks' which require drawings to be checked and signed by a second person as well as the designer before they are issued. This would be considered by the designer as loss of his autonomy and increasing dependence to others.

7.6 Quality Assurance through Changing Corporate Culture

Corporate culture is the pattern of values, beliefs, and norms shared by organisation members. It has been recognised that corporate culture has an powerful impact on the implementation of business strategy and Organisational effectiveness (Ouchi, 1979; Pascale, 1981; Deal and Kennedy, 1982; Peters and Waterman, 1982). The success of Japanese companies on quality, to a great extent, can be explained by their strong company-wide quality-oriented corporate culture (Ishikawa, 1984b).

Although the major objective of quality assurance is to produce evidence of quality through the implementation of quality systems, the essence of quality assurance is to deliver quality by eliminating human mistakes from the production process. Quality systems construct the organisational structure for quality management. However, the human aspect of quality management, including quality awareness, attitudes, motivation, and commitment are all important to the achievement of the error-free quality objective.

An effective way to promote the human aspect of quality management is to build the value of quality into the centre of the company's culture. However, corporate culture is not something which can be changed overnight. It needs persistent long term effort. To create a corporate quality culture, the following steps should be taken:

(1). Recognising the need for change: Need for change has to be recognised and communicated to all members of the corporate. It should include information on 'Why change is necessary' and 'What need to be changed'. These are achieved through various training and education programmes.

(2). Setting up the goals for change: After 'What need to be changed' have been recognised, clear Organisational goals are to be set up. There goals include the company's new value, belief, attitude and commitment on quality.

(3). Making use of the culture network: While the planned organisational changes are implemented across the formal structure and bureaucratic system of the company, the role of the culture network should not be neglected. Deal and Kennedy (1982) describe the culture network as the primary but informal means of communication within an organisation compounded by storytellers, spies, priests, cabals, and whisperers. It is the 'carrier' of the corporate values and heroic mythology. It could be a

considerable resistant force to any change which is not in favour with members of the network. However, by taking advantage of the informal network, its members can be various kinds of change agents to implement the change effectively.

(4). Reinforcing new value system by heroes, rites and rituals: Heroes, rites and rituals help to reinforce the new value system by symbolise it. Chief executives and quality managers, by their supports and contribution to quality programme can well become the company's heroes. Other members of the companies who have made remarkable contribution to quality improvement can also become the quality heroes of the company and the models for other people to follow. Quality prizes, new quality improvement campaigns, and an annual 'Quality Day' can be useful rites and rituals for the reinforcement of the company's belief and commitment on quality.

Chapter 8 The Macro Quality Assurance System in the Fire Protection Industry

This chapter presents the studies in the issue of quality assurance in fire safety engineering from a perspective of the industry as a whole. The concept of macro quality assurance system is discussed and a theoretical model is proposed. The components and the processes of the macro quality assurance system in the fire protection industry are examined.

8.1 Introduction

Quality of fire safety engineering in buildings, with its direct relevance to safety of human life and property, is not only the concern of the builders and the clients, but also the concern of various social groups and organisations ranging from government bodies and business organisations to individual users of the buildings. Research results that have been presented in Chapter 7 indicate that most fire safety engineering firms feel external pressure that demands quality assurance. Such external pressure is an important factor that affects the development of quality assurance in these firms. A notable finding of the research is that such pressure is produced not only by clients, but also by various social groups and organisations such as government, insurers, certification bodies, fire authorities, building authorities, and trade and professional bodies (See Table 7.2). It is recognised that these groups and organisations have formed a social environmental setting within which fire safety engineering firms operate their quality assurance programmes. A detailed study of the environmental setting provides a deeper understanding on the development and implementation of quality assurance in the fire protection industry.

Investigations were carried out to examine the processes through which these social groups and organisations exercise their influence on the issue of quality assurance. Research data in this part were constructed by both fieldwork and library research in relevant publications and documents, as it has been described in Chapter 4.2.

The concept and a theoretical model of the macro quality assurance system were developed to describe the industrial and social environmental settings within which quality assurance is operated, and to explain the relationships between them. Particularly, the macro quality assurance system in fire protection industry was described in detail.

8.2 The Concept of Macro Quality Assurance Systems

The highly competitive market provides consumers with a wider range of choice of quality products. Experience in quality has increased the consumer's awareness of 'value for money'. Consumers are now becoming far more concerned with quality than they were before. Price is no longer the most prominent factor that influences purchase decisions. Consumers are demanding higher levels of quality.

Having perceived the market demand for quality, manufacturers have recognised that quality is becoming a dominant factor among those that determine gains and losses of market share. Quality is not only a matter of business ethics, but essential for business survival. Companies who are not concerned with the quality of their product and services will take the risk of being out of business.

From the viewpoint of an industry or a nation, quality provides a strong support to win in the international markets. The Japanese experience demonstrates that quality can make significant contribution to the development of economy. The 1982 UK Government White Paper (DTI, 1982) recognises the importance of the quality at the highest level in the UK. It clearly spelled out the message: Quality is the key to re-establishing Britain's position as a leader in the world market.

Quality is therefore not only the concern of individual suppliers and consumers, but also the concern of all aspects of the society. A number of social groups and organisations that are not in the supplier-purchaser chain become actively involved in the industrial practice of quality assurance and tend to enhance their influence on the processes that the suppliers deliver their products and services. These groups and organisations construct a social structure that contribute to the management of quality within the related industry. Such a social structure can be defined as a macro quality assurance system.

In BS5750/ISO9000, a quality system is defined as 'the organisational structure, responsibilities, procedures, processes and resources for implementing quality management'. Such a quality system is operated within a supplier's organisation, and can be referred as a 'micro' quality system in comparison with a macro quality assurance system. While BS5750 Quality Systems outline the quality assurance operations in the supplier's organisations, a macro quality assurance system defines and co-ordinates the quality assurance operation of an industry on a macro scale.

The structural model of a macro quality assurance system is illustrated in Figure 8-1. It consists of four parts: the inputs, processes, process-servers, and outputs.

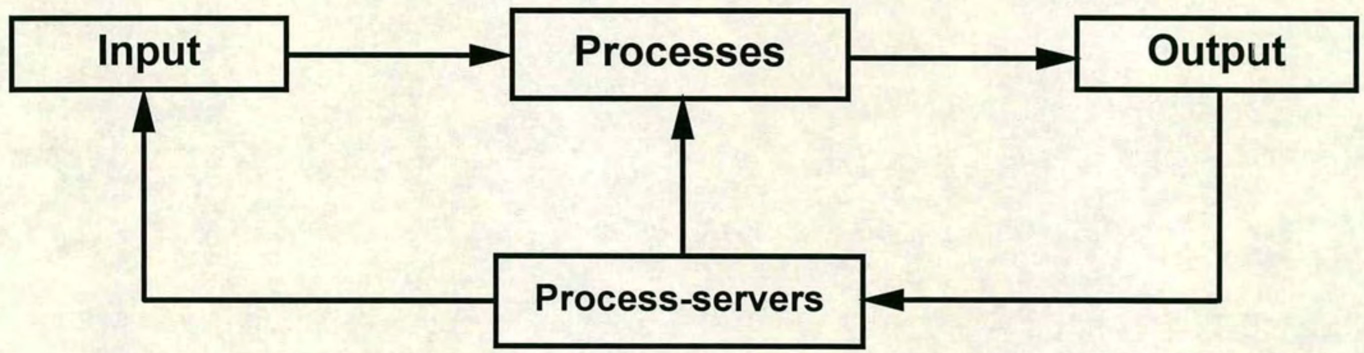

Figure 8.1 The modal of a macro quality assurance system

The inputs of the system are the quality requirements for the products and services that the industry is offering. These requirements include the expectation of customers and clients, as well as the social expectation at large such as those concerned with health, safety and environment.

The system processes are a series of quality activities that aim at promoting quality assurance and improving quality in the industry. These processes can be classified into three categories: regulatory processes, technical processes, and informational and supportive processes. Regulatory processes are concerned with the legislation and regulation that are related to quality practice in the industry. They include laws and regulations, quality accreditation and certification, unification of measurement and calibration. Technical processes involve production, implementation and revision of technical standards, codes of practice and specifications of the products and services. Informational and supportive processes are activities that provide information and other support relating to quality assurance. These include education and training, quality awards, quality campaign, quality consultation, publication, conferences and seminars as well as research. A summary of these processes is presented in Figure 8-2.

Process-servers are organisations and persons that activate, implement, and control the processes. The roles of the process-servers are to receive and interpret the system inputs, to carry out the processes, and to monitor and feed back the outputs. They can be generally categorised into three groups or levels: the regulatory level, the liaison and information support level, and the business operational level. At the regulatory level, the process-servers carry out the work of legislation and regulation, which include both the administrative aspect and technical aspect. Major process-servers at this level are the government, quality accreditation and certification bodies, standards institutions, and other regulatory bodies such as local authorities. At the liaison and information support level, the process-servers provide communication between various parties such as the suppliers, purchasers, professional, regulatory bodies and other relevant parties. They also promote the use of information and the enhancement of quality awareness through various means such as those specified in the category of informational and supportive processes. At the business operational level, the process-servers are mainly involved in the quality assurance activities through business operation of purchasing products and services and supplying raw materials.

In Figure 8-3, the major process-servers are listed in three groups. In this list these organisations are grouped by the major roles that they are playing in the macro quality assurance system, with a purpose of illustrating the theoretical structure of the process-servers. However, these organisation are usually at more than one of the three levels. For example, while trade associations works as liaison and information support bodies in the system, they are also actively involved in legislation and regulation. The government is in fact involved in all the three levels of activities. Detailed discussions of the roles of some of the organisations are presented in the next section where the macro quality assurance system of the fire protection industry is examined.

The four part of the macro quality assurance system are the outputs that are produced by the system. In general, they are presented by the improvement of quality assurance practice in the industry. These include the recognition and application of quality

Processes:

A. Regulatory: Laws and Regulations
Quality Accreditation
Quality Certification
Measurement and calibration

B. Technical: Standards
Codes of Practice
Specifications

C. Informational and supportive:
Education and training activities
Quality awards
Quality campaign
Quality management Consultation
Publications
Conference and seminars
Scientific research

Figure 8-2 The processes of a macro quality assurance system

Process servers:

A. Regulatory level:
   - Government
   - Quality accreditation bodies
   - Quality certification bodies
   - Standards Institutions(such as BSI)
   - Other regulatory bodies (such as local authorities)

B. Liaison and information support level:
   - Trade associations
   - Industrial professional institutes
   - Quality management professional organisations
   - Educational and research institutions

C. Business operational level:
   - Consumer's associations
   - Large purchaser organisations
   - Large supplier organisations

Figure 8-3 The process-servers of a macro quality assurance system certification schemes and quality standards, promotion of quality management in the companies, and improved quality performance of products and services in the industry at large.

Macro quality assurance systems are established on the basis of individual industries. This means that each industry has an unique macro quality assurance systems. The word 'industry' here means a group of firms that serve a distinct market with similar products or services. To each industry, the macro quality assurance system has its own features and characteristics. Particularly, the inputs and the process-servers of each macro quality assurance system vary from one industry to another. This is because of the distinct nature and requirement of the specific products, services, and technologies that the industry deals with; and the specialised industrial organisations that are operated in the industry as process-servers, such as specialised certification bodies and trade associations.

The following section of this chapter presents the results of the examination into features of the macro quality assurance system in fire protection industry. The major process-servers of the system are identified, and the processes and the roles of these process-servers are analysed.

8.3 The Macro Quality System in the Fire Protection Industry

In the context of fire safety engineering, the macro quality assurance system is characterised by the special features of its input, processes, process-servers, and output.

The particular requirements for fire safety engineering have been discussed in Chapter 5.3. These requirement make the inputs of the macro quality assurance system distinctive from those in other industries. In particular, it is necessary to review the following three points:

(1). Fire safety is the interest of every member of society. It is a concern of all social groups and organisations. While fire safety equipment and systems are used comprehensively in modern buildings, the quality of such equipment and systems is as important as their designed functions.

(2). When an ordinary consumer product loses its function, the scope of the damage is most likely to be limited within the supplier-purchaser circle. However, the failure of fire safety equipment in the case of fire may lead to serious social consequences. Thus, quality of fire protection products is a special concern of the society.

(3). Some building clients and users may not be aware of the need for particular fire safety equipment and systems. Also, they may not be aware of the requirement for some particular quality characteristics of the fire safety equipment and systems. While quality is defined in fire safety engineering, it should consider not only the expectation and requirement of the clients and users, but also those of the society at large.

The traditional structure of the fire protection industry sets up a 'unique' social framework within which the issue of quality is concerned. This framework constructs the process and the process-servers of the macro quality assurance system. Some special processes and process-servers are not usually to be found in macro quality assurance systems in other industries. For example, the involvement of fire authorities and insurance companies.

The processes and process-servers of the macro quality assurance system in fire protection industry are presented in Figure 8-4 (a) and (b). In Figure 8-4 (b), the process-servers are grouped into three categories by the major roles that they are playing in the system. However, these process-servers are playing their roles at more than one levels. The remaining part of the section discusses the roles of these process-servers and examines how the processes are implemented.

The Government

The government's concern for fire safety is primarily the protection of human life. Its basic role on quality assurance is acting as a regulator and a promoter.

The Fire Precautions Act 1971 (Anon, 1971) grants the government the power to make orders to designate premises where fire certificates are compulsory. The 'Fire Precautions (Hotels and Boarding Houses) Order 1972' (ANON, 1972) and the 'Fire Precautions (Factories, Offices, Shops and Railway Premises) Order 1989' (ANON, 1989) are the Designating Orders that have specified a range of types of buildings where compulsory fire certification is applied. Fire certification provides a means of control for the fire authorities to ensure that certain levels of fire safety has been maintained in these buildings.

The Building Regulations (Anon, 1991) is one of the most important pieces of delegated legislation relevant to fire safety in buildings. They define the fundamental requirements of fire safety in buildings. In the context of quality assurance, they give guides to the performance

Processes:

Regulatory:	Laws and Regulations, esp. Fire laws and Building Regulations Sectoral quality accreditation and certification schemes for the fire protection industry Measurement and calibration
Technical:	Standards, Codes for Practice, Specifications relevant to design, manufacture, installation, and maintenance of fire safety engineering systems and components
Informational and supportive:	Activities that have influence or direct relevance to quality management practice in the fire protection industry, such as Education and training activities Quality awards Quality campaign Quality management Consultation Publications Conference and seminars Scientific research

Figure 8-4(a) The processes of the macro quality assurance system in the fire protection industry

Process servers:

A. Regulatory level:
   - Government
   - Insurers
   - Quality certification bodies
   - Building authorities
   - Fire authorities
   - Other national process-servers, such as the BSI and NACCB

B. Liaison and information support level:
   - Trade associations and professional institutes, such as BFPSA, BAFE, FETA, IFS, and FPA
   - Educational and research Institutions

C. Business operational level:
   - Consumer's associations
   - Large purchaser organisations
   - Large supplier organisations

Figure 8-4(b) The process-servers of the macro quality assurance system in the fire protection industry requirements of fire safety equipment and systems by referring to relevant Codes of Practice and British Standards. The fire resistance test that is specified in the Building Regulations is regarded as a traditional way of quality control in the fire protection industry.

The government works as a promoter of quality assurance through its involvement in a series of activities, including encouragement of independent certification schemes, the development of a national accreditation system, publication of the Government White Paper (DTI, 1982) and the launching of the National Quality Campaign (DTI, 1986b). The impact of these movements in fire protection industry resulted in the development of various Quality Assurance Schemes by related quality certification bodies like LPCB (the Loss Prevention Certification Board) and BSI (British Standards Institution).

The government also exercises its influence on quality assurance through its public purchase plans. The 1982 Government White Paper (DTI, 1982) pointed out that the public purchasers can play an important role in improving the competitiveness of their suppliers through relating the purchase requirements to national or international standards and by making great use of independent quality certification. The Property Services Agency (PSA), one of the largest government agencies in the construction industry, did make a great deal of progress in implementing such a policy (DTI, 1986b).

Insurers

The insurers play a significant role in the fire protection industry. With the principle objective of property protection, the fire insurers are involved in a wide range of activities concerned with fire safety in buildings. Quality of the fire protection equipment and systems in the buildings has been one of their major concerns. Their activities in quality assurance are mainly in 3 categories: (1) standards-making; (2) quality certification; and (3) procurement control.

The Loss Prevention Council (LPC), backed by the insurers, publishes a comprehensive series of performance standards. These are the Loss Prevention Standards (LPS) that define the insurer's requirements for fire safety equipment and systems. While some of these standards are identical to the British Standards, others are supplemental. These standards are recognised and used widely in design, specification, manufacture, and installation of fire safety equipment and systems. Examples of these standards include the 'Rules for Automatic Sprinkler Installations'(LPC, 1990), 'Rules for Automatic Fire Detection and Alarm installations for the Protection of Property'(LPC, 1986).

The Loss Prevention Certification Board (LPCB), an authoritative quality certification body in the field of fire safety engineering, is a constituent member of the Loss Prevention Council. The link between LPCB and the insurers enable the insurers to influence LPCB's certification criteria and policy. On the other hand, the authoritative position of the LPCB is strengthened by the insurer's recognition of its certification mark.

In many cases, fire safety designers tend to seek the insurer's involvement in the design and specification stage of the building. This early involvement enables insurers to influence and control the design of the fire safety systems and the specification of the fire protection products to be used. Therefore, insurers are able to contribute to the quality of design and advise or require their clients to procure quality products and services.

Quality Certification Bodies

Quality assurance is about providing evidence that is needed to establish confidence for the quality of the products or services. Certification bodies are the medium through which quality assurance is accomplished, for quality certification marks are regarded as evidence of quality in the markets.

The major role of the certification bodies is to ensure that the certified companies have achieved and maintained satisfactory levels of quality management conforming to the standards. This role is carried out through quality audits and inspections.

With the authority of the certification marks being recognised in the markets, the certification body possesses power to influence the status quo of quality assurance within the related industrial area. Research data suggest that changes in quality certification schemes can have powerful influence over the quality assurance practice within the industry. This is evidenced by the impacts that were caused by the advance of the LPCB's quality schemes in recent years. The Loss Prevention Certification Board has announced its plan to replace its traditional quality approval schemes with new quality certification schemes. The new certification schemes requires that the certified companies possess quality systems in accordance with BS5750/ISO9000 (LPCB, 1987; LPCB, 1991). This new requirement has worked as a driving force to speed up the adoption of the BS5750/ISO9000 Quality Systems among the fire safety engineering firms. Some quality managers suggested in the interviews that their companies would not have established the quality systems had it not been mandated by the LPCB's new certification schemes.

Building Authorities

The building authorities work as a regulator and a quality controller in the context of fire safety in buildings. The Building Act 1984 (ANON, 1984) defines that it is the responsibility of the building authorities to ensure that the Building Regulations(ANON, 1991) have been followed throughout the design and construction of the building. It is required that the design of a new building is subject to the approval of building authorities before construction is commenced.

One task of the building authorities is to ensure that the fire safety design of the building conforms to the Regulations that have been made under the Building Act. This enables the authorities to control the quality of fire safety design in general. While a particular piece of fire safety equipment or system is concerned, the building authorities may require that its performance conforms to the relevant British Standard.

At the commissioning stage of the building construction, representatives from building authorities work as quality inspectors to ensure that the completed building is in compliance with its approved design and specification.

The new 1991 Building Regulations (ANON, 1991) promote the use of the engineering approach to fire safety design. This allows more flexibility for the design of the fire protection systems. However, it is important to ensure that the alternative engineering methods can achieve adequate levels of fire safety in the buildings. A key issue that is concerned with the achievement of the adequate fire safety is the quality of fire safety design and the quality of the engineering facilities that are used.

Fire Authorities

The Fire Precautions Act 1971 (ANON, 1971) and relevant Fire Precautions Orders entrust the fire authorities to carry out compulsory fire certification to certain types of buildings. The Fire Safety and Safety of Places of Sport Act 1987 (ANON, 1987) further grants the fire authorities the power to serve Prohibition Notices without reference to a court. Such Notices would forbid the notified buildings from certain types of use.

The purpose of fire certification is to ensure the provision of adequate means of escape and related fire precautions in the designated premises. Although fire certification is primarily concerned with the availability and adequacy of these fire safety measures, it is obvious that quality and reliability of the facilities provided are the unstated prerequisite for such availability. It has not become a common practice for the fire authorities to require quality certification of the fire safety equipment and systems installed in the buildings. However, some fire certificates may refer the fire safety equipment and systems to the relevant British Standard, for example, 'a smoke detection system to comply with BS5839 Part 1 at the L2 standard' (BSI, 1988b). In some cases, when the fire inspectors are not confident about the quality of some fire equipment, they may ask for test reports or other evidence of quality assurance. It is expected that in the future quality assurance of the fire safety equipment and systems will become a more important requirement in fire certification.

Unlike the building authorities, the fire authorities have no legal role in the design and construction stages of the building. Fire certification is carried out when the building comes to be occupied. However, building owners and contractors may consider it necessary to seek advice from the fire authorities on the fire safety design. Therefore, like the insurers and the building authorities, fire authorities are also able to contribute to the quality of fire safety design.

Trade and Professional Bodies

The influence on the development of quality assurance that a trade association can produce is seen in the example of the British Fire Protection Systems Association (BFPSA).

The BFPSA states that one of its principle objectives is 'To uphold and enhance the professional status of the Fire Protection Industry by encouraging the adoption of improved standards for personnel training, systems design, equipment quality and after-sales service' (BFPSA, 1992).

As an influential trade association in the fire protection industry, it has been actively involved in developing standards and codes of practice for fire protection systems and equipment even since its early days. Representatives of BFPSA are invited to join in the relevant working groups of the BSI and ISO.(Jones, 1991)

Quality certification is another area that BFPSA has been involved in during recent years. It has worked together with the Loss Prevention Certification Board in the development and launch of the 'LPS 1014 Quality schedule and Requirements for Fire Alarm System Installing Companies'(LPCB, 1987a). It also works closely with the British Approvals for Fire Equipment (BAFE) to pursue a series of goals in relation to the promotion of third party quality certification.

BFPSA works as a liaison between the regulatory bodies and the industries. It is one of the founder members of the UK Sectoral Committee Operating for Fire and Security (SCOFS), whose objective is to represent the collective views of manufacturers, users and third parties responding to perceived market demands for conformity assessment in the UK Fire and Security Sector. Its links with the regulatory bodies provide valuable channels to deliver the concern of the industry to the regulatory bodies. On the other hand, it informs its member companies about any changes or potential changes in legislation that may affect the industry.

Other trade and professional bodies, such as the British Automatic Sprinkler Association, the Fire Extinguishing Trades Association, and the Institution of Fire Engineers, play their roles more or less as the same as the BFPSA. They promote the communications among industry companies, professionals, their clients, and the regulatory bodies. The demands for quality has become a prominent message that is now spread out through these organisations. Professional bodies like the Institution of Fire Engineers and the Fire Protection Association also work for education and training to improve the competence of the professionals. The competence of professionals should always be fitted into the framework of the industry quality assurance schemes, for the competence of the staff is the prerequisite to the achievement of quality of work.

8.4 Summary and Further Discussions

In summary, quality of fire safety equipment and systems in buildings is not only the concern of the users and suppliers, but also the concern of a number of social groups and organisations. Such social groups and organisations provide a framework of the macro quality assurance system and contribute to the development of quality practice in various ways. Having discussed the functions of the major components of the system in previous sections, it is meaningful to further highlight the following points:

(1). The roles of the consumers and clients in quality assurance have been recognised as an essential driving force for the development of quality systems. The client group of the fire safety engineering industry consists of building clients, building contractors, building services contractors, or other purchasers of fire safety equipment and systems. The way that the clients influence the quality practice of a fire safety engineering firm is straight forward: their demands for quality system certificates are usually specified as a condition for tender.

(2). The objective of the macro quality assurance system is to achieve satisfactory quality of the fire safety engineering in buildings. Quality assurance in the fire safety engineering firms is the key to the achievement of such a objective. Therefore, an immediate task of the macro quality assurance system is to promote quality assurance in the fire safety engineering firms.

(3). In recent years, the focus of quality assurance has been on the development of quality certification and the use of BS5750/ISO9000 Quality System. BS5750/ISO9000 provides an excellent framework for the 'micro' quality systems to be operated in the companies. However, it can be argued that the introduction of such a quality system does not always lead to the development of sound quality management practice. Many companies are now working toward a 'total quality' approach. The 'total quality' approach requires changes in the attitudes to quality and changes in the company's culture. It is essential that a 'quality climate' is built up within the industry, through the work of the macro quality assurance system, to encourage and support the development of the 'total quality' approach.

(4). With the development of quality certification schemes, the problem of multiple testing and assessment from different certification bodies becomes a worry to some companies. In recent years certification bodies, as well as organisations like British Approvals of Fire Equipment (BAFE) and British Fire Protection Systems Association (BFPSA), have made considerable efforts to harmonise the certification and approvals activities that are operated in same fields. However, because of the industry tradition and the complicated structure of the fire protection industry, this problem is likely to remain for a certain period of time.

(5). In a building project, the parts of fire safety engineering are usually divided into a series of separate work packages. These separate packages are then contracted to various firms at various stages. Such fragmented procurement processes require a systematic approach to assure quality of the project.

The macro quality assurance system is an important part of the overall approach to the 'total quality'. It develops an essential environmental setting for quality assurance of an individual company and an individual project. While the needs for quality have been widely recognised in the construction industry, it is meaningful to examine the matter of quality assurance on a broad background. The macro quality assurance system of the fire protection industry should be fitted within the total system of the whole construction industry.

Chapter 9 Evaluation of Effectiveness of QA in Fire Safety Engineering Firms

Evaluation of the effectiveness of the quality assurance programme is as important as the successful implementation of quality assurance. Previous Chapters have discussed the development and implementation of quality assurance in fire safety engineering companies. This chapter is to examine the existing methods that are used to assess the effectiveness of quality management programmes, and explores the applications of these methods for evaluation of the effectiveness of quality assurance programmes in fire safety engineering firms.

9.1 Why is it important to evaluate the effectiveness of quality assurance?

The instinctive goal of a business organisation is to make profits. Every activity in the organisation has to be conducted in line with this goal. So do quality activities. A number of motivators for quality assurance have been summarised in Chapter 7. They are customer's need, market competition, development of certification schemes, and business development strategy. Lascelles and Dale (1991) suggest that the motivators of quality improvement can be categorised as: (1) catalyst of change, including competition and need to reduce costs; (2) change agents, including demanding customers and the chief executive; (3) change opportunities, including greenfield ventures and restart situations.

To explore this issue further, it is not difficult to see that the basic motive force behind the motivations listed above is to make the operation of the business more profitable through these quality activities. Hence, the best yardstick to judge the effectiveness of the quality management systems will ultimately be financial, as it is to other management functions.

Garvin (1988) argues that quality must be closely associated with such key measures of business performance as cost, market share, and profitability. Otherwise, quality improvement would quickly lose its appeal for it would lack a strategic rationale.

The theory of 'quality costs' was discovered in 1950's and has been applied in many fields of manufacture to assess the cost-effectiveness of a quality improvement programme. Other methods are also used to measure the actual improvement of quality and the attainment of quality objectives. Chapter 9.2 reviews the current methods that are currently used for evaluation of quality improvement programmes. However, these methods are designed to assess quality programmes that are aimed at improving quality and saving costs. The improvement of product quality and savings of costs through those programmes are usually measurable. Quality assurance, however, is to ensure that the products and services are delivered at a certain quality level which meets the customer's requirement. Its original purpose is not to improve quality or reduce costs, although effective operation of quality assurance will result in improvement in quality and cost reductions.

It is believed that quality assurance can bring many benefits into the company. However, a problem that remains is that how would we know that these benefits have been achieved, and how we would know that the quality assurance programme is effective. The results from the literature search showed that there were few sophisticated explanations for the association between implementing quality assurance and key business variables such as cost, market share, and profitability. There is a need to explore the evaluation methods that provide systematic assessment to the effectiveness of quality assurance and provide analytic tools for management decisions.

9.2 Current practice in evaluating the effectiveness of quality programmes

In current practice, evaluation of the effectiveness of quality programmes such as Quality Improvement, Quality Circles, Total Quality Management, are made from three major aspects: quality, cost-effectiveness, and organisational change.

(1). Quality

The actual measurement of quality is the most significant indicator for all quality programmes. Products and services are inspected and tested against specifications. Results of the inspection and tests are compared throughout the operation of the programmes. Any improvement in the quality performance of the products and services gives straight evidence to demonstrate the programme's effectiveness.

Quality of products and services are measured in several ways which can be categorised as subjective measurements and objective measurements. Subjective measurement of quality is derived from the concept that quality is to satisfy the customer's need, while objective measurement of quality is defined by conformance to specifications.

Subjective Measurement

Quality is to satisfy customer's need. It is therefore essential to identify the customer's need and to measure the customer's satisfaction. In product design, customer's need should be recognised and translated into product specifications. At the stage of product appraisal and development, customer's satisfaction is of vital importance to the assessment of quality. Concepts such as 'quality characteristics' and 'quality dimensions' are invented to define and analyse customer's need, while 'quality of design' and 'quality of specification' are the measure of customer's satisfaction. Market survey is an effective way to find out what the customers really want. However, it must be kept in mind that customer's need and customer's satisfaction are subjective matters that are affected by perception and preference, although quantitative methods can be employed to measure consumer's attitudes. Therefore, measurement of quality in these circumstances tend to be subjective rather than objective.

The concepts of 'quality dimensions' and 'quality characteristics' were invented for defining quality so that they could be measured. Juran (1979) defines that any feature (property, attribute, etc.) of the products, materials, or processes which is needed to achieve quality is a quality characteristic. These characteristics can be categorised into several groups, including technological characteristics such as hardness, inductance, acidity; psychological characteristics such as taste, beauty, status; time-oriented characteristics such as reliability, maintainability; contractual characteristics such as guarantee provisions; and ethical characteristics such as courtesy of sales personnel, honesty of service shops. Garvin (1988) suggests that the measurement of quality consists of 8 dimensions: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. It is not necessary that these 8 dimensions are universally applicable to all products. Some products may have more or less quality dimensions than 8. However, the concept of 'quality dimensions' provides a framework on which customer's need can be defined and analysed.

During the stage of design and specification, the concept of 'Quality of design' and 'quality of specification' are applied to measure quality in design and specification activities.

Juran (1979) defined the term 'quality of design' as quality of a composite of three categories of activities: market research, concept, and specification (Also see Chapter 5.5.3). Accordingly, 'quality of design' can be broken down and assessed by 'quality of market research', 'quality of concept' and 'quality of specification'.

Market surveys are popular methods to examine consumer's attitudes to a product, usually carried out at two phases in a product life circle: product planning and product development. In product planning, market surveys are used to identify the customer's need; while in product development they are used to assess to customer's satisfaction and to investigate the customer's further need.

A recent development in evaluating customer's need and customer's satisfaction is the 'kansei' study (Nishina and Ishigami, 1993). 'Kansei' is defined as the capability to translate stimulus into impressions. The impressions are translated into technical terms and scaled with scores, and then associated with physical characteristics. An outstanding feature of 'kansei' study is that it translates feelings and subjective impressions to quantitative data and associates them with physical characteristics of the product. It provides a new way of measuring quality and defining quality characteristics.

Other methods of market surveys for evaluating quality include questionnaire surveys to customers, retailers, servicemen and women, etc. Such questionnaire surveys can be carried out to investigate the surveyee's attitudes to any aspects of quality from customer's satisfaction on single quality characteristics to brand quality rankings.

Another aspect of the subjective measurement of quality involves some qualitative features of the product which can not be specified in numerical terms, such as appearance, colour and taste. Measurement of such quality characteristics rely on judgement from the senses and experience.

Objective measurement

Crosby (1979) suggests that quality must be made measurable so that it can be measured. He emphasises the objective measure of quality which is the technical conformity of the product to its design and specification.

The rate of nonconformity is often used for the measurement of quality and they are used in various circumstances. The famous Quality Control Charts were developed to reflect the rate of nonconformity.

Quality control charts are effective tools for measuring and monitoring quality in production processes. They are categorised as the attributes control chart and the variables control chart. An attribute, as used in statistical quality control, refers to a quality characteristic that does or does not conform to specifications. Attributes control charts can be used to monitor the conformities of a quality characteristic, a manufactured item, or a product unit. They are particularly useful for measuring the qualitative quality characteristics such as colour and taste. A variable is a quality characteristic that can be expressed as numerical measures. Variables control charts are used mainly for measuring quality characteristics that can be inspected by test instruments.

Field quality is quality in customer's hands, or in other words, quality of the products that have been sold and used for a certain period of time. It is an important part of total quality. Service call rates, customer's return rates, and customer complaint rates are usual measures to field quality. Service calls are trips made by servicemen to customer's homes or by customers to service shop to repair the appliances. Drawbacks of using service calls rates to measure field quality are that there is no standardised method to calculate the rates and that the accuracy of service call rates is influenced by some uncontrollable factors, for example delay of the customer's calls,

Rates of nonconformity and defect are also used to measure field quality. However, these measurement share the same weakpoint with service calls rates the problem of accuracy.

There are other proposals for measurement of quality. For example, Hutchins (1984) suggests that the measures of quality in relation to the success of a Quality Circles programme can be made by using data such as: defects per man hour, scrap per unit manufacture, and customer return data.

(2). Cost-effectiveness

The concept of 'quality costs' was first referred to as 'Gold in the Mine' (Juran, 1951). It was focused on the 'avoidable costs of quality'. The implication of the concept was that costs resulting from defects, which can be avoided by eliminating the defects, were a 'gold mine' where profitable digging could be done.

Feigenbaum (1983) categorised quality costs into two major groups: costs of control, and costs of failure of control. The costs of control consist of two segments: prevention costs and appraisal costs. Prevention costs are the costs that prevent defects and nonconformities from occurring and include the quality expenditures to keep unsatisfactory products from coming about in the first place. Included here are such cost areas as quality engineering and employee quality training. Appraisal costs include the costs for maintaining company quality levels by means of formal evaluations of product quality. This includes such cost areas as inspection, test, outside endorsements, quality audits, and similar expenses.

The costs of the failure of control, which are caused by materials and products that fail to meet quality requirements, are also measured in two segments: internal failure costs, which include the costs of unsatisfactory quality within the company, such as scrap, spoilage, and reworked material, and external failure costs, which include the costs of unsatisfactory quality outside the company, such as product-performance failures and customer complaints.

Plunkett and Dale (1991) observed that ideas of what constitute quality costs have been changing rapidly in recent years. It is now widely accepted that quality costs are the costs incurred in designing, implementing, operating and maintaining quality management systems, plus the costs incurred owing to failures of systems or products. They arise from a range of activities, e.g. sales and marketing, design, R & D, purchasing, storage, handling, production planning and control, manufacturing, delivery, installation and service. Suppliers, subcontractors, stockists, agents, dealers and especially customers can also influence the incidence and level of these costs.

Quality costs can be an indicator of the effectiveness of a quality improvement programme. As the quality programme progresses effectively, the failure costs decrease with a smaller increase in control costs (costs of prevention plus costs of appraisal), resulting in a large decrease in the total quality costs. However, there have been to some difficulties that prevent the concept of quality costs from wider application. One of the difficulties is the classification of the costs that are and are not related to quality.

(3). 'Soft' Measurement of Quality Progress

The 'soft' measurement of quality progress refers to the assessment to the achievement of those organisational goals set in the quality programme that are related to human behaviour and corporate culture, such as quality awareness, motivation and commitment. Evaluation on the progress in such 'soft' aspects of a quality programme is usually based on the goal-attainment model. A good example is given by Kelly al et (1991) in their practice to evaluate the Total Quality Management programme in their company, as reviewed below.

In implementing the Total Quality Management, a series of statements were developed which formed a vision of TQM in their company. These statements included:

1. Everyone is focused on "meeting customers' agreed requirements at lowest cost first time, every time".

2. Everyone is striving for zero defects and improved

productivity.

3. For teams and individuals success and effort is genuinely recognised and rewarded.

4. Everybody has a clear understanding of their role and responsibilities within the organisation.

5. Everyone is identifying and consistently reducing the cost of poor quality.

6. Realistic action and contingency plans exist in each unit and are used as the basis for management of change.

7. All managers are trained and demonstrating an agreed range of skills.

8. Managers have realistic action plans for development and career succession paths for people in their teams.

9. Everyone will give and receive feedback effectively as an essential part of continuous improvement.

10. Individual and team targets and milestones are consistently achieved.

11. There is effective team working at and across all levels and divisions.

12. All managers will take full responsibility for effectively managing change to achieve specified outcomes.

13. Underperformance in any area is consistently identified, challenged and corrected.

14. Everyone is demonstrating ownership for their own learning.

These vision statements set up the organisational goals that lead to the achievement of a companywide 'total quality culture'. In the next step, a set of measures are developed to assess progress. These measures include both quantitative measurement that are defined in numerical terms and qualitative assessment that are carried out through questionnaire surveys among employees.

For example, to Statement No.2 "Everyone is striving for zero defects and improved productivity", the measures that are defined are "the operational goal of zero defects" and "the responses to staff attitude survey questions 'Improving quality is part of my normal job'".

Statement No.3 "For team and individuals success and effort is genuinely recognised and rewarded" and Statement No.4 "Everybody has a clear understanding of their role and responsibilities within the organisation" are purely subjective and are based on the perception of the staff. Measures to these two Statements were obtained from the responses to staff attitude survey questions "How satisfied are you with the recognition you receive for doing your job well"? "I have enough information to do my job well" and "I understand what is expected of me in my own job".

The goal-attainment model and staff attitude survey in Kelly et al (1991) case are effective measures to assess the behaviour change in quality programmes. Some other measures that can indicate the change of behaviour achieved by the quality programmes include labour turnover, absenteeism, reduction in accidents, stoppages (Hutchins, 1984).

9.3 Evaluating the effectiveness of quality assurance: with special reference to the practice in fire safety engineering firms

In general, the methods that are used for evaluating the effectiveness of quality improvement programmes, reviewed above can also be used in quality assurance programmes. However, the aims and operational processes of a quality assurance programme are different from those of a quality improvement programme. Therefore, modification are required when these methods are used for quality assurance. This section examines the features of quality assurance and methods for evaluating the effectiveness of quality assurance programmes.

An intensive literature search was carried out and no publications have been found which give systematic reviews on the effectiveness of quality assurance and the evaluation methods. Some literature studying the effectiveness of quality improvement programme are reviewed in last section. Case studies were carried out in eight fire safety engineering companies to investigate the practice that they assess the effectiveness of their quality assurance programmes. The investigation were carried out to examine their practice from four perspectives: (1) Quality, (2) Costs, (3) Behaviour change, and (4) Quality systems.

(1). Quality

Measures for inspection and testing were established in all case companies. These measures are part of are the requirement of the BS5750 Quality Systems. All four manufacturing companies had employed statistical process control. Installation companies carry out inspection and testing for every installation. The results of inspection and testing are recorded and analysed.

In theory, the nature of a quality improvement programme usually falls into one of the three categories: troubleshooting, breakthrough, and new product and process planning. The purposes of the quality improvement programmes in any category are to achieve a superior level of performance from current state. Quality assurance however is aimed at producing and maintaining a constant level of quality.

While the inspection result indicates that quality of the products or installations are constantly maintained at the satisfactory level, the implication is that the quality assurance programme is operating effectively.

It must be pointed out that to use the results of inspection and test effectively the inspection and test have to be carried out accurately. This requires that the inspection, measuring and test equipment are controlled, calibrated and maintained appropriately, and that the operations are carried out without human errors. Such requirements are defined in BS5750 and quality procedures are implemented in the quality systems to ensure that the requirements are met.

In some fire safety system installation companies, client's complaints and service calls are used as a complementary measure to assess quality and subsequently the effectiveness of the quality systems. But they are not treated as important measures because of several reasons: Such complaints and service calls appear occasionally. Some are not real quality problems but the client's or user's mistakes. One quality manager claimed that the client's complaints to their companies were rare. However, client's complaints are used by quality managers to find out quality problems and as warnings to increase the employee's quality awareness.

(2). Quality Costs

During the research, there was no evidence showing that the method of quality costs had been used for evaluation of quality assurance, neither from fieldwork nor from published literature.

None of the case study companies have employed the quality costs methods. It is believed that the need for introducing the methods of quality costs has not been recognised by the fire protection industry. In current practice, the evaluation of cost-effectiveness of the quality assurance programmes is made out of the management's judgement that the quality assurance programmes have brought in some benefits and therefore are 'value for money'.

Another reason of not using the quality costs methods was that these companies were relatively small-sized firms. Because of their low turnover, breakdowns of quality costs were small and therefore were not meaningful enough for management decisions.

The method of quality costs was developed from manufacturing. It has not been a popular practice in the construction industry and its applicability in construction is still to be explored. Also, its purpose is to demonstrate the effectiveness and benefits of quality improvement. It is suggested that when it is used for quality assurance, some development in the details of the methods are needed. The application of quality costs is not required in BS5750/ISO9000 Quality Systems.

(3). Behavioural Change

Effective implementation of quality assurance requires organisation change, particularly changes in quality attitudes and work behaviour. However, such changes are not easy to be measured. Kelly et al (1991) give a good example of measuring the organisational goals in the behavioural aspect of total quality management. In theory, questionnaire surveys can be an effective approach to reveal employee's attitudes. However, its practicability in fire safety engineering companies is to some extent limited. An obvious reason for this is that in small companies with only some a dozen employees a questionnaire survey would be too formal to be carried out.

Only one of the case companies reported that a questionnaire survey was conducted among the company's employees in which quality attitudes were a part of the survey objectives, but detailed contents and results of the survey were treated as confidential and therefore not accessible.

Instead of formal questionnaire survey, quality managers used their personal contacts on formal or informal occasions to gain the information on employee's attitudes to quality and quality systems. Quality managers believed that such methods were effective.

Internal quality audits are among the formal contacts to assess behavioural change, and are proven to be effective. Nonconformities to the quality systems that are found in the quality audit are usually due to human errors. It is expected that when everybody implements the quality system in a conscientious manner the nonconformities can be reduced to zero.

Top management's commitment to quality is one of the most important factors to the achievement of quality assurance. It is usually stated in every quality manuals that the management ensure their commitment to quality. However, there is no immediate way to verify whether the statement has been achieved or not. While the installation of the quality system can demonstrate the good will of the top management in quality, it does not automatically prove that the real quality commitment has been achieved. In one case, both the managing director and quality manager of the company revealed their resentful attitudes to the LPCB, the certification body whom they thought that made BS5750 compulsory in the industry and created extra burdens for their company. It is in doubt that this company, although it gained a quality certificate for their quality system from LPCB, has achieved a real commitment to quality in its top management.

After all, assessment of the commitment of the top management is a difficult matter. The real test for the top management, as Ockland (1989) suggests, is when urgent orders arrive and maintaining the level of quality requires sacrificing profit.

(4). Quality Systems

The most important aspect in the evaluation of quality assurance is of course the assessment of the quality system itself. The quality system lies in the heart of quality assurance. It defines the organisational structure, responsibilities, process and resources that are necessary for ensuring the conformance of products to specified requirements, and provides written procedures and instructions which describe the way that the quality operations are conducted in the company.

There are two types of assessment for quality systems: the external quality audit and the internal quality audit. The external quality audit is carried out by an external quality auditor, usually from the quality certification body with whom the quality system is registered, while the internal quality audit is usually carried out by quality manager of the company.

The external audit is conducted for the purpose of quality certification. Its result is reported to both the certification bodies and the management of company assessed. Such results provide an objective evaluation of the effectiveness of the quality system. Corrective actions are required for any nonconformities observed in the quality audit. Serious nonconformities can lead to failing of the quality certification and withdrawal of the quality certificate.

Internal quality audit is quality manager's inspection of the quality system. The requirements and operation procedures of internal quality audits are defined as a part of the quality system. It is commonly regarded by the companies involved in the study as the most effective way to evaluate the effectiveness of the quality system. In some small fire safety systems installation companies, the quality audit is the only measure that is used for the evaluation.

Quality audits reveal the conformance or nonconformance of the quality system to the stated requirements. Nonconformity rates are compared between departments to help the quality managers allocate problems and seek improvement. In two cases, the quality managers emphasised their use of the reduction in nonconformity rates as an effective indicator of the improvement of the companies' quality cultures. In other cases, it also revealed that quality audits can provide some information about the attitudes of the personnel who operate the quality system. Such information is very useful for the quality manager to evaluate the quality attitudes of the employees.

While quality audits are used to examine the effectiveness of the quality system, it should not be regarded as the sole measure for evaluating the quality assurance programme. Assessment of quality, costs and behavioural change are complementary measures that should be adopted. Quality audits can confirm that the company implements an effective quality system. However, possession of such a system only demonstrates the company's capability of delivering products and services complying with specified requirements, but does not guarantee that the management has committed itself to doing so. Further more, the effectiveness of the quality system does not reflect the cost effectiveness of the overall quality assurance programme.

(5). Conclusion

To conclude this chapter, it is suggested that a systematic approach to evaluate the effectiveness of quality assurance programmes should combine all of the following four aspects: assessment of quality, analysis of quality costs, evaluation of behavioural change, and assessment of the quality system. While assessment of quality and quality systems has been practised in most fire safety engineering companies, the application of quality costs system and evaluation on quality behaviour need to be promoted. Further research is needed to explore how the quality costs system and behavioural science can be best applied in the context of quality assurance in the fire safety engineering firms.

Chapter 10 Conclusions and Discussions

This chapter is to conclude the research findings that are presented in previous chapters, and to discuss the interpretation of these findings in the theoretical and practical context of fire safety engineering and quality management. These conclusions and discussions were organised under five sub-titles in line with the five aspects of the research that have been presented in Chapters 5~9 of this thesis. In the final section of this Chapter some topics for further research are recommended.

10.1 Defining Quality in Fire Safety Engineering

Fire safety engineering is the application of engineering concepts of techniques for the achievement of fire safety in buildings. The objectives of fire safety engineering are to protect life and property in the building, as well as the building itself, from unexpected fire, and to prevent the fire from conflagration. To achieve such objectives, a fire safety assurance system is produced in the building through the application of fire safety engineering. The fire safety assurance system can be seen as a combination of two sub-systems: the fire safety system and the managerial safety system. (Figure 5.1) The fire safety system is the engineering part of the total system which is presented by the assembly of fire safety equipment, material and structures in the building, while the managerial safety system is the totality of managerial measures for fire safety that are employed in the building after it is occupied.

As quality assurance is concerned in the context of fire safety engineering, it is the quality of the 'hardware' part of the 'fire safety system' that should be made certain and measurable. The essence of defining quality in fire safety engineering is defining the quality of the fire safety system.

The model for defining quality of a fire safety system, which is developed on the basis of theoretical interpretation into the concept of quality and the research data from the fieldwork, consists of two perspectives: (1) Quality Dimensions; and (2) Quality Processes.

(1). The quality dimensions of a fire safety system include the followings:

- Performance
- Reliability
- Durability
- Maintainability (Serviceability)
- Economy
- Aesthetics

To make quality manageable, the first step is to make quality certain. This means the requirement for the products and services should be defined in a way that they can be measured and assessed. To define the quality of a fire safety system, it is essential to study into the requirement in the six dimensions specified above. Quality characteristics of the fire safety systems in all the six dimension should be specified into measurable terms so that they can be inspected and tested objectively. Those quality characteristics that can not be quantified should be specified as clear and accurate as possible to limit differences caused by any subjective assessment.

These six dimension are applicable to the fire safety system that is to assembled in the building as well as to its sub-systems and components. During the process of design, manufacture and installation of the sub-systems and components, quality must be defined upon all these six dimensions.

(2). The major quality processes of fire safety engineering involves:

- Quality of design
- Quality of manufacture
- Quality of installation
- Quality of maintenance

It has been widely recognised now that quality can not be achieved by merely using the means of inspection and testing. Quality is designed in. Quality is built in. To achieve quality in a fire safety system, constant efforts must be made throughout every stage of the process of fire safety engineering.

However, the nature and objectives of the activities involved in each stage of the process are featured with focused attentions. It is important to define the quality objectives in each stage of the process. That is to say that quality objectives should be specified throughout design, manufacture, purchase, installation, commissioning and maintenance. Quality of the fire safety system is achieved through the achievement of quality objectives at every stages of the fire safety engineering.

The last aspect of defining quality is the specification of the competence of professional. Quality is achieved at the hands of the people who are actually doing the jobs. While quality assurance provides a rationalised framework for delivering high quality, it will only be effective when the quality systems are operated by qualified persons.

The link between quality and professional competence is established in BS5750 Quality Systems in which it states:

> "The supplier shall establish and maintain procedures for identifying the training needs and provide for the training of all personnel performing activities affecting quality. Personnel performing specific assigned tasks shall be qualified on the basis of appropriate education, training and/or experience, as required."

However, the standard of training and qualification concerned with a specific job has to be defined under that particular circumstance. In the context of fire safety engineering, because of the short history and the diverse nature of the profession, the issue of professional competence in quality assurance practice has great importance and should be emphasised from the point of views of both quality assurance and professional development.

10.2 Quality assurance in fire safety engineering projects

In a building project, the part of fire safety engineering is managed in one or more packages and procured in various ways. Research work was carried out to examine the organisation of quality assurance activities in the procurement of fire safety systems in building projects. The scope of examination also included the projects that were carried out for the specific purpose of refurbishing fire safety facilities and updating the fire safety level in existing buildings.

The major building procurement systems in current construction practice include: the traditional system, construction management for a fee, separate contracts, project management, the British Property Federation System, and package deal system and design-and-build (Franks, 1984). Research found that organisation of the fire safety engineering package in building projects is influenced by the building procurement system that is employed in the projects. The procedures of procuring fire safety engineering packages vary accordingly with the building procurement system. However, detailed studies into each type of the procurement show that fire safety engineering companies, who are usually subcontractors in building projects, have formulated their working procedures to limit the influence of the variation of building procurement systems. It proved to be possible to generalise the procurement process of fire safety systems in building projects into five stages. These are

(1). Brief of fire safety requirements;

(2). Concept design of the overall fire safety system;

(3). Organisation of fire safety engineering packages;

(4). Procurement of fire safety sub-systems;

(5). Commissioning of the total fire safety system.

Based on the generalisation of the procurement processes, a systematic framework for quality assurance of fire safety systems in building projects is developed. It must stated that the aim of framework developed is to provide a general guidance for quality assurance of fire safety engineering in building projects. The principles that are outlined in the framework will be valuable to the development of detailed quality plans and quality procedures for specific types of procurement.

A framework for assuring quality of fire safety engineering in building projects is developed which is based on systematic project quality planning with the support of systematic quality management in the firms. It consists of three levels:

Level A: Total System Quality Planning, which establishes a Quality Plan for the overall fire safety in the building project;

Level B: Sub-system Quality Planning, which establishes a set of Quality Plans for individual fire safety sub-systems;

Level C: Quality assurance in fire safety engineering companies, which establishes the Quality Systems for organisation and management of quality activities in the companies.

The Total System Quality Planning requires a systematic view on the procurement of the overall fire safety engineering in the building project. In current practice, fire safety engineering in a building project is usually divided into separate packages and procured by different subcontractors. This is because of the nature of the work and the tradition of the industry. Research indicated that such traditional practices have some shortcomings in terms of quality assurance, particularly in such aspects as defining quality responsibilities, controlling interfaces between individual packages, co-ordinating the work of sub-systems. The Total System Quality Planning is to aim at improving the organisation and co-ordination of individual fire safety engineering packages and sub-systems, and overcoming the limitation of traditional procurement systems.

In the Total System Quality Planning, fire safety engineering, or the 'total fire safety system', in the building project is treated as an integrated package. The Total System Quality Plan defines the organisation and management of overall fire safety engineering in the project.

Sub-system Quality Planning produces a set of quality plans for fire safety sub-systems. A prominent feature in the procurement of fire safety sub-systems is that these sub-systems are usually designed, installed and commissioned by different subcontractors. It is suggested that the Sub-system Quality Plans should be developed on a project basis rather than a sub-contractor basis with the emphasis co-ordination between different teams. This means there should be one Quality Plan for one sub-system, rather than one Quality Plan for one subcontractor.

The Total System Quality Plan and The Sub-system Quality Plans establish the structure and define the procedures for managing quality in the project. Detailed requirements for the Total System Quality Plan and the Sub-systems Quality Plans are presented in Section 6.3.

A fire safety system is a collective product of a number of fire safety engineering companies, including subcontractors and components manufacturers. Quality assurance in these companies is essential for achieving quality in the fire safety engineering projects. The 'on-site' Quality Planning for the fire safety engineering project should be based on a high level of 'in-house' quality assurance in fire safety engineering companies. Without 'in-house' quality assurance, quality of the products and services that these companies supply to the building project can not be assured.

Some modifications are required when the BS5750/ISO9000 Quality Systems are applied in fire safety engineering firms because of the special features of their operations. Principal guidance for the modification are suggested in Section 6.3 for fire safety engineering firms in both the manufacturing sector and the construction sector.

In summary, a systematic approach to quality assurance of fire safety engineering in building projects consists of Total System Quality Plan, Sub-systems Quality Plans and 'in-house' quality assurance in fire safety engineering firms. It is a 'grounded theory' that is produced on the 'ground' of scientific research. It is predicted that it will provide a useful guide to the future development of quality assurance in fire safety engineering.

10.3 Quality assurance in fire safety engineering firms

Quality assurance has been put into practice in many fire safety engineering firms with the introduction of the BS5750/ISO9000 Quality Systems. It is suggested that the implementation of quality assurance is a process of organisational change. Successful organisation change is essential to the achievement of the effectiveness of the quality systems. In the research, the causes and effects of the introduction of the quality systems in fire safety engineering firms have been identify. A number of factors that affect the process of organisational change have been recognised.

Causes and Effects

There are four major reasons that fire safety engineering firms start to introduce quality assurance into their organisations. These are: (1). client's need; (2). market competition; (3). development of certification schemes; and (4) the company's business development strategy. They work as major motivators to promote the development of quality assurance in these companies.

In general, an increasing number of fire safety engineering firms have recognised the necessity of adopting quality assurance to meet client's need and to advance in market competition. However, it has to be pointed out that such a necessity has not been recognised by all companies that were surveyed. Research data indicated that the most common reason for quality assurance in these companies was the pressure from the certification body. The great impact that the certification body produces on the development of quality assurance is a quite special feature in the fire protection industry. The research also found that such an impact can generate both positive and negative effects. It is no doubt that the pressure from the certification bodies can accelerate the progress towards quality assurance in the industry. But such pressure can also produce reluctance and negative attitudes that undermine the effectiveness of the quality systems. Research results suggest that companies who adopted quality assurance as business development strategies implement the quality systems effectively.

The survey revealed that fire safety engineering firms have experienced both benefits and drawbacks of quality assurance. The benefits include

- formalising work procedures,
- improving traceability of work,
- improving communication,
- improving organisation efficiency,
- improving quality,
- reducing error and mistakes, and
- improving marketing competitiveness.

The major drawbacks are increase of work burdens and financial burdens.

It is hoped that with the further development of the application of the quality systems the drawbacks will be eventually eliminated and more benefits will be seen.

Factors affecting the effectiveness of quality assurance

The factors that influence the organisational change that is brought about by introducing quality assurance, and subsequently affect the effectiveness of quality assurance in fire safety engineering firms include:

- The gap between different goals
- Previous experience in quality management
- External pressure
- Leadership and change agents
- Company size
- Business activities

A number of human factors that cause resistance to the required changes in an organisation are also identified. These are:

- Lack of awareness of the need for change
- Misunderstanding and lack of trust to the effectiveness of the quality systems
- Fear of losing investment in the status quo, including
- Fast education and experience
- Fear of losing job security
- Fear of losing autonomy in working

Above all, the most important factors that influence the effectiveness of quality assurance are attitudes and commitment to quality, and the corporate culture of the company.

It is suggested that to implement quality assurance effectively it is essential to develop within the company a 'total quality' culture. To create such a corporate quality culture, the top management should make its true commitment to quality and lead a companywide organisational culture change.

The human aspect of quality assurance has attracted great attention from many researchers and practitioners. This is evidenced from some recent publications on this topic that have been reviewed earlier in the thesis. However, there is a need for scientific investigation with systematic and controlled research methodologies. The present research was focused on the experience of fire safety engineering firms and therefore the scope of the investigation was limited. It is hoped that it will provide a framework for further research into the topic and the theories presented here will be verified by investigation on a larger scale in the future.

10.4 The Macro Quality Assurance System

It is recognised that quality of fire safety engineering is not only the concern of the buyers and the suppliers, but also the concern of the society. The research found that some social groups and organisations such as the government, insurers, quality certification bodies, building authorities, fire authorities, trade and professional bodies exercise significant influence on the development of quality assurance in the fire protection industry. These groups and organisations form the social environmental settings within which fire safety engineering firms operate their quality assurance programmes.

The concept of 'macro quality assurance system' is proposed to describe the general structure and processes which are established by the social environmental settings for the development of quality assurance. Figure 8.1 in Chapter 8 has presented a structural model of a macro system which consists of the input, processes, process-servers and output. The input is the requirements of quality for the products and services. The processes are a series of quality activities promoting quality assurance within the industry, such as legislation, certification, quality education and publicity campaign. Process-servers are organisations and persons that activate, implement, and control the processes. They receive, interpret and transmit the input, and monitor and feedback the process-servers. The output of the system is the promotion and support that the system produces to the quality assurance activities in the industry.

It is suggested that each industry possesses a specialised macro quality assurance system. The major features of the macro quality assurance system are derive from the characteristics of the products and services that the industry is dealing, the organisations that form the process-servers, and the particular processes the are associated with the structure of the industry.

In fire protection industry, the input of the macro quality assurance system is the requirements for quality of fire safety equipment and systems. Fire safety is the concern of all members of the society. So should be the quality of fire safety equipment and systems. Such concern is particularly perceived and transmitted to the fire protection industry by some social groups and organisations who function as the process-servers in the macro quality assurance systems. These groups and organisations include: the government, insurers, quality certification bodies, building authorities, fire authorities, trade and professional bodies. They activate, implement, and control the processes that promote and support the development of quality assurance practice in the fire protection industry. These processes involve fire safety legislation, enforcement of the legislation and regulations, development of Technical Standards and Codes for Practice for fire safety equipment and systems, establishment and implementation of sectoral quality accreditation and certification schemes, publication of information about quality, organisation of conference and seminars, and research in quality assurance.

While quality is recognised as a very important factor to the development of economy and the improvement of quality of life, the meaning of quality has gone beyond the scope of business. It is believed that nation-wide striving for quality improvement is becoming the new strategy of economic development in many countries. With the development of national and industrial schemes for quality, the role of the macro quality assurance system will more influential than at present. Theoretical research into the rationale and principle of macro quality assurance systems will provide valuable insights in industrial environment within which quality is delivered. However, it is reasonable to conclude, from the current situation in the fire protection industry, that both the theory and practice of macro quality systems are still in the early stage of development. There is a need for consciousness and recognition of such a macro system and a need for improvement in the integration and co-ordination of the system components.

10.5 Evaluation of Quality Assurance Programmes

Evaluation of the effectiveness of a quality assurance programme is an essential for the management to review the progress and to make decision on further operation. Methods for evaluating quality improvement and other quality programmes have been reviewed in Chapter 9.2. It is suggested that these methods can also be used for quality assurance programmes in general, although some modifications and supplementations are needed.

It is suggested that a systematic approach to evaluating the effectiveness of a quality assurance programme should involve four aspects of assessment: (1) quality, (2) cost, (3) behaviour change, and (4) the quality systems.

Research data indicated that the evaluation of the effectiveness of quality assurance programmes in fire safety engineering firms were not adequate. Quality audits to the quality systems were used as prominent tools to assess the quality systems. However, assessment in other aspects were overlooked. Systematic evaluation practice involving all above four aspects were not established.

A particular problem is the difficulties related to assess the quality costs in fire safety systems installations. It is understood that the existing theory of quality costs, which is developed for the manufacturing activities, does not fit well with the construction practice. However, there is a necessity to assess the cost-effectiveness of the quality management practice in construction firms. Therefore, further research should be carried to develop practical methods for analysing and evaluating quality related costs in the fire safety engineering firms, and as well as in other construction firms.

10.6 Topics for Future Research

Some issues that need further studies have been mentioned throughout the discussions presented in previous sections of the Chapter. As a summary, four topics for future research are recommended:

(1). The human aspect of quality assurance in construction: The research in the human behaviour aspect of quality assurance that has been presented in this thesis can be extended to other sectors of the construction industry. While quality assurance is now a popular approach adopted by the construction companies, a systematic study of the 'human factors' that affect the effectiveness of quality assurance in construction will gain insights into the organisational change process through which the companies promote their quality assurance practices toward 'total quality'.

(2). Total quality management in fire safety engineering: The focus of the present research has been on the theory and practice of quality assurance. As many companies are planning for their Total Quality Management, a need emerges for the examination of the Total Quality Management approach in the context of fire safety engineering. It is predicted that the features of fire safety engineering firms and the fire protection industry will produce some special effects on the application of the Total Quality Management. Research into this topic will enhance the understanding of Total Quality Management in the very particular industrial sector.

(3). The macro quality management system in the construction industry: The theory of macro quality assurance system, or macro quality management system in a broader sense, can be applied to other sectors of the construction industry. It can be used to explore the social environmental factors that influence the quality practice in the construction industry and to describe a macro picture of the quality management in the industry, and therefore will produce useful new knowledge of industrial structure and process of quality management.

(4). Application of quality costs in construction, with particular reference to building services engineering and fire safety engineering: The need for analysing and evaluating quality related quality in construction should be recognised and effective methods should be developed. Two particular areas of investigation in this topic involve: (i) the application of quality costs in design and installation of building services systems and fire safety systems; (ii) the application of quality costs in small size construction firms.

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Appendix 1 Sample Questions for Interviewing

1. What are the major reasons for the company to introduce quality assurance? and why?

2. How was the quality system in the company developed? Who initiated the Quality Assurance Programme? Who was responsible for the development of the quality system? How many people were involved in the early stage of the programme?

3. How was the quality system introduced into practice? How were the staff trained to implement the quality procedures?

4. How was the implementation of the quality system monitored? How was its effectiveness evaluated?

5. Why was the company registered with the particular certification body(s)? How did the company feel the influence of the certification bodies?

6. What measures were taken to motivate the staff at all levels to implement the quality system effectively?

7. What did the staff think about quality, quality assurance and the quality system? How did you (the quality manager) know about the staff's attitudes? What measures were taken to change any negative attitudes?

8. What changes had occurred in the company since it started to introduce quality assurance? How did the staff respond to the changes?

9. What were the major negative responses and resistance to the changes having been experienced in the company? How did you (the quality manager) deal with them?

10. Apart from the quality system, what other quality programmes and techniques, such as Quality Circles, Statistical Quality Control, Quality Costs, and Total Quality Management, were operated in the company? Why or why not?

11. How were quality audits carried out? How often were they carried out? and by who? How were the results reported? How were corrective actions taken?

12. How were the project contracts managed? And how were the projects organised? Could you describe some typical processes for contracting and managing fire safety engineering and systems in building projects?

13. How do you deal with quality assurance in individual projects? How is quality assurance implemented through each stages of the project construction processes?

14. How do you review the contracts? How do you ensure that the client's requirement has been understood fully and interpreted correctly in the design and specification?

15. How is the quality plan for an individual project prepared and managed? Who is usually in charge of the quality plan? Who makes it? Who reviews it? Who audits it?

16. How is the quality plan implemented in the context of the building project, particularly when other parties of the building project have no quality assurance system in their organisation?

17. How do you ensure that the installation work have been carried out in accordance with the design and specification?

18. How does the project team co-ordinate with the main contractor, the architect and the building services engineering teams?

19. How did the company project teams co-operate and co-ordinate with other parties of the building projects? Please give examples.

20. How did the project teams deal with the regulatory bodies, such as building authorities, fire authorities, and insurers?

21. How was the company controlling the subcontracted labour?

22. How were the warranty and/or after-sales services maintained? Were quality data of the warranty services used for measuring and analysing quality of the systems?

23. How do you relate the commitment to quality with the effectiveness of the quality system? How do you relate the value of quality and the corporate culture with quality assurance?

24. How do you think about quality assurance and Total Quality Management according to the business practice of your company?

Appendix 2 A Sample Questionnaire for the Postal Survey

A Survey on Quality Assurance in Fire Safety Engineering Firms

Note for guidance in completing questionnaire:

1). The majority of questions have been given possible answers, please tick the boxes provided and where appropriate please tick as many options as required.

2). For those open-ended questions, if the given space is not sufficient, please use additional sheets. It is appreciated that the answer is written in block letters.

1. In which of the following business activities is your company involved?

(a). Design and/or installation of sprinkler systems ☐

(b). Manufacture of sprinkler systems and components ☐

(c). Design and/or installation of fire alarm and/or detection systems. ☐

(d). Manufacture of fire alarm and/or detection systems and components. ☐

(e). Design/manufacture/installation of fire doors and shutters ☐

(f). Design/manufacture/installation of smoke control equipment and systems ☐

(g) Others ☐

2. Please indicate number of employees in your organization:

(a). Under 10 ☐

(b). 10~29 ☐

(c). 30~49 ☐

(d). 50~99 ☐

(e). 100+ ☐

3. Please indicate the range of annual turnover of your company in last financial year.

(a). Under £1m ☐

(b). £1~2m ☐

(c). £2~5m ☐

(d). £5~10m ☐

(e). £10~50m ☐

(f). £50m+ ☐

4. Do you obtain project contracts from the following?

(4A). Professions:

(a). Architect ☐

(b). Quantity Surveyor ☐

(c). Structural Engineer ☐

(d). Building Services Engineer ☐

(e). Fire Engineer ☐

(f). Project Manager ☐

(g). Others (please specify) ☐

(4B). Trade:

(h). General Building Contractor ☐

(i). Management Contractor ☐

(j). Building Service Contractor ☐

(k). Other Fire Safety Systems Installation Company ☐

(l). Others (please specify) ☐

5. From within your clients from Question 4, which is the most important to your company?

____

6. (a). When did your company decide to introduce the BS5750 Quality System?

Year________ Month________

(b). When did your company received the certificate for the BS5750 Quality System? (If your Quality System has more than one certificate, please give the Year and Month that the first certificate was obtained.)

Year________ Month________

(c). By which certification body was your Quality System certificated?(If your Quality system has more than one certificate from different certification bodies, please give the names of all the certification bodies and the date of the registrations.)

____

____

7. Did your company have any formal quality control or quality management procedures before BS5750 was introduced?

Yes ☐ No ☐

If "yes", please elaborate the coverage of the previous quality procedures (e.g. contract review, design control, document control, etc.).

____

____

____

____

____

8. At the time when your company started a QA programme to introduce BS5750 Quality Systems, did you feel pressure from outside of your company demanding QA?

Yes ☐ No ☐

9. If "Yes" to question 8, please indicate from which of the following your company felt pressure:

(a). Government ☐

(b). Fire authorities ☐

(c). Building authorities ☐

(d). Clients ☐

(e). Certification Body(s) ☐

(f). The British Standard Institution ☐

(g). The Loss Prevention Certification Board ☐

(h). Other Certification organization(s) ☐

(i). Insurers ☐

(j). Trade Associations ☐

(k). Fire safety professional institutes ☐

(l). Business rivals ☐

(m). Other (please specify)________________________________ ☐

10. Among the pressures caused by the group and /or organizations as you indicated in question 9, which one of them is the most important and direct driving force for your company to get the QA certification.

____

11. If "No" to question 8, please explain why your company started implementing QA.

____

____

____

____

12. Do you ever receive postal questionnaires or have any visits from your clients in regard to your quality management (e.g. questionnaires asking if your company has quality control procedures, BS5750 quality system, etc.)

(a). Never ☐

(b). Occasionally ☐

(c). Not much in the past, but increasing recently ☐

(d). Frequently in the past a few years ☐

13. At the early stage of your company's QA programme, when the Quality System was prepared and developed, and when the new quality procedures were introduced and implemented, who do you think played the most important role in pushing the programme forward?

(a). The managing director of your company ☐

(b). The quality manager in your company ☐

(c). The consultant from the certification body ☐

(d). The consultant from the QA consultant company ☐

(e). Others (please specify)____________________________ ☐

14. After your Quality System has been approved, who has been expected to play the most important role in keeping the system working?

(a). The managing director of your company ☐

(b). The quality manager in your company ☐

(c). The consultant from the certification body ☐

(d). The consultant from the QA consultant company ☐

(e). The quality auditor from certification body ☐

(f). Others (please specify)______________________________ ☐

15. Do you think that QA is cost-effective in your company?

(a). Yes ☐

(b). No ☐

(c). Not at this stage, but it will be in long term ☐

(d). Not sure ☐

16. The following are believed to be the benefits of QA, which of them have been seen in your company so far?

(a). Improved communication ☐

(b). Formalized working procedures ☐

(c). Improved organization's efficiency ☐

(d). Improved marketing competitiveness ☐

(e). Increased traceability of the work ☐

(f). Improved quality ☐

(g). Reduced error and mistakes ☐

(h). Other (please specify)_______________________________________ ☐

(i). Have not seen any. ☐

17. Please rank the benefits that you indicated in question 16 by filling the heading letters in the boxes. If there are more than 3, please rank the 3 most important ones. If there are less than 3, please leave the rest of the boxes empty.

1. ☐ 2. ☐ 3. ☐

18. The following are the possible drawbacks or "side-effects" of QA. Which of them have, to a certain extent, been experienced in your company?

(a). Increased extra financial burden ☐

(b). Increased extra work burden ☐

(c). Increased bureaucracy and reduced efficiency ☐

(d). Other (please specify) ________________________________ ☐

(e). Have not seen any. ☐

SUMMARY OF RESPONSES TO THE QUESTIONNAIRES:

(1). BUSINESS ACTIVITIES: RESPONSES TO QUESTION NO.1

BUSINESS ACTIVITIES	Count	% of Responses	% of Cases
SPRINKLERS INSTALLER	17	20.5	30.4
SPRINKLERS MANUFACTURER	15	18.1	26.8
DETECTORS INSTALLER	12	14.5	21.4
DETECTORS MANUFACTURER	15	18.1	26.8
D/M/I FIRE DOORS	11	13.3	19.6
D/M/I SMOKE CONTROL	2	2.4	3.6
OTHERS	11	13.3	19.6
Total responses	83	100.0	148.2

0 missing cases; 56 valid cases

(2). NUMBER OF EMPLOYEES: RESPONSES TO QUESTION NO.2

NUMBER OF EMPLOYEES	Count	Percent	Valid Percent	Cum Percent
UNDER 10	3	5.4	5.4	5.4
10~29	10	17.9	17.9	23.2
30~49	10	17.9	17.9	41.1
50~99	12	21.4	21.4	62.5
100+	21	37.5	37.5	100.0
Total	56	100.0	100.0	

Valid cases 56 Missing cases 0

(3). ANNUAL TURNOVER IN 1992

ANNUAL TURNOVER	Count	Percent	Valid Percent	Cum Percent
UNDER £1m	2	3.6	3.8	3.8
£1~2m	12	21.4	23.1	26.9
£2~5m	14	25.0	26.9	53.8
£5~10m	5	8.9	9.6	63.5
£10~50m	17	30.4	32.7	96.2
£50m+	2	3.6	3.8	100.0
missing	4	7.1	Missing	
Total	56	100.0	100.0	

Valid cases 52 Missing cases 4

(4). CLIENT GROUPS OF THE FIRE SAFETY ENGINEERING COMPANIES

Client Groups	Count	Pct of Responses	Pct of Cases
ARCHITECT	38	11.8	70.4
QUANTITY SURVEYOR	25	7.7	46.3
STRUCTURAL ENGINEER	12	3.7	22.2
BUILDING SERVICE ENGINEER	33	10.2	61.1
FIRE ENGINEER	15	4.6	27.8
PROJECT MANAGER	39	12.1	72.2
CLIENT	10	3.1	18.5
GENERAL CONTRACTOR	34	10.5	63.0
MANAGEMENT CONTRACTOR	39	12.1	72.2
BUILDING SERVICE CONTR5ACTOR	35	10.8	64.8
OTHER FSS INSTALLATION FIRM	28	8.7	51.9
INSURER	3	.9	5.6
CONSULTANT ENGINEER	2	.6	3.7
OTHERS	10	3.1	18.5
Total responses	323	100.0	598.1

2 missing cases; 54 valid cases

(5). RANKING OF CLIENT GROUPS

Client Group	Count	Percent	Valid Percent	Cum Percent
ARCHETECT	7	12.5	24.1	24.1
OTHER FSS INSTALLATION FIRM	3	5.4	10.3	34.5
INSURER	2	3.6	6.9	41.4
CONSULTANT ENGINEER	2	3.6	6.9	48.3
OTHERS	3	5.4	10.3	58.6
BUILDING SERVICE ENGINEER	2	3.6	6.9	65.5
PROJECT MANAGER	1	1.8	3.4	69.0
CLIENT	3	5.4	10.3	79.3
GENERAL CONTRACTOR	4	7.1	13.8	93.1
MANAGEMENT CONTRACTOR	2	3.6	6.9	100.0
MISSING	27	48.2	Missing	
Total	56	100.0	100.0	

Valid cases 29 Missing cases 27

(6). QUALITY ASSURANCE PROGAMMES: RESPONSES TO QUESTION NO.6

A. MONTHS OF PREPARATION

Months	Count	Percent	Valid Percent	Cum Percent
LESS THAN 6	3	5.4	6.8	6.8
6~12	19	33.9	43.2	50.0
13~18	11	19.6	25.0	75.0
19~24	8	14.3	18.2	93.2
MORE THAN 24	3	5.4	6.8	100.0
MISSING	12	21.4	Missing	
Total	56	100.0	100.0	

Valid cases 44 Missing cases 12

B. MONTHS OF IMPLEMENTATION

Months of Implementation	Count	Percent	Valid Percent	Cum Percent
LESS THAN 12	5	8.9	9.3	9.3
12~24	19	33.9	35.2	44.4
25~36	11	19.6	20.4	64.8
MORE THAN 36	19	33.9	35.2	100.0
MISSING	2	3.6	Missing	
Total	56	100.0	100.0	

Valid cases 54 Missing cases 2

(6c). HOUSES OF REGISTRATION

HOUSE OF REGISTRATION	Count	Percent	Valid Percent	Cum Percent
LPCB	24	42.9	43.6	43.6
BSI	3	5.4	5.5	49.1
LRQA	2	3.6	3.6	52.7
BASEC	2	3.6	3.6	56.4
LPCB+BSI	20	35.7	36.4	92.7
LPCB+ELSE	4	7.1	7.3	100.0
MISSING	1	1.8	Missing	
Total	56	100.0	100.0	

Valid cases 55 Missing cases 1

(7). PRE-EXPERIENCE: RESPONSES TO QUESTION NO. 7

Pre-experience		Count	Percent	Valid Percent	Cum Percent
NO		30	53.6	53.6	53.6
YES		26	46.4	46.4	100.0
	Total	56	100.0	100.0	

Valid cases 56 Missing cases 0

(8). EXTERNAL PRESSURE: RESPONSES TO QUESTION NO.8

External pressure		Count	Percent	Valid Percent	Cum Percent
NO		14	25.0	25.0	25.0
YES		42	75.0	75.0	100.0
	Total	56	100.0	100.0	

Valid cases 56 Missing cases 0

(9). SOURCES OF EXTERNAL PRESSURE: RESPONSES TO NO.9

Source of pressure	Count	Pct of Responses	Pct of Cases
GOVERNMENT	10	8.1	23.8
FIRE AUTHORITIES	10	8.1	23.8
BUILDING AUTH.	7	5.6	16.7
CLIENT	24	19.4	57.1
BSI	4	3.2	9.5
LPCB	29	23.4	69.0
OTHER CERT. ORG.	4	3.2	9.5
INSURERS	9	7.3	21.4
TRADE ASS.	9	7.3	21.4
FIRE PROF. INST.	4	3.2	9.5
BUSINESS RVL	14	11.3	33.3
Total responses	124	100.0	295.2

14 missing cases; 42 valid cases

(10). RANKING OF PRESSURE: RESPONSES TO NO.10

Source of pressure	Count	Percent	Valid Percent	Cum Percent
CLIENTS	16	28.6	42.1	42.1
LPCB	19	33.9	50.0	92.1
INSURERS	1	1.8	2.6	94.7
TRADE ASSO.	1	1.8	2.6	97.4
BUSINESS RVL.	1	1.8	2.6	100.0
MISSING	18	32.1	Missing	
Total	56	100.0	100.0	

Valid cases 38 Missing cases 18

(11). QUESTIONNAIRES RECEIVED: RESPONSES TO QUESTION NO.12

Questionnaires Received	Count	Percent	Valid Percent	Cum Percent
NEVER	1	1.8	1.8	1.8
OCCASIONALLY	15	26.8	26.8	28.6
INCREASING	9	16.1	16.1	44.6
FREQUENTLY	31	55.4	55.4	100.0
Total	56	100.0	100.0	

Valid cases 56 Missing cases 0

(12). CHANGE AGENT 1: RESPONSES TO QUESTION NO.13

A. MULTICOUNT CODING:

Change agent	Count	% of Responses	% of Cases
MANAGING DIRECTOR	30	39.5	53.6
QUALITY MANAGER	33	43.4	58.9
CONSULTANT	9	11.8	16.1
OTHERS	4	5.3	7.1
Total responses	76	100.0	135.7

0 missing cases; 56 valid cases

B. EXCLUSIVE CODING:

Change agent	Count	% of Responses	% of Cases
MANAGING DIRECTOR	19	33.9	33.9
MANAGING DIRECTOR & QUALITY MANAGER	11	19.6	19.6
QUALITY MANAGER	22	39.3	39.3
CONSULTANT	3	5.4	5.4
OTHERS	1	1.8	1.8
Total responses	56	100.0	100.0

0 missing cases; 56 valid cases

(13). CHANGE AGENT 2: RESPONSES TO QUESTION NO.14

A. MULTICOUNT CODING:

Change agent	Count	% of Responses	% of Cases
MANAGING DIRECTOR	11	16.2	19.6
QUALITY MANAGER	50	73.5	89.3
CONSULTANT	0	0.0	0.0
QA AUDITOR	3	4.4	5.4
OTHERS	4	5.9	7.1
Total responses	68	100.0	121.4

0 missing cases; 56 valid cases

B. EXCLUSIVE CODING:

Change agent	Count	Pct of Responses	Pct of Cases
MANAGING DIRECTOR	5	8.9	8.9
QUALITY MANAGER	44	78.6	78.6
MANAGING DIRECTOR & QUALITY MANAGER	6	10.7	10.7
OTHERS	1	1.8	1.8
Total responses	56	100.0	100.0

0 missing cases; 56 valid cases

(14). COST-EFFECT: RESPONSES TO QUESTION NO.15

Cost-effective	Count	Percent	Valid Percent	Cum Percent
YES	35	62.5	62.5	62.5
NO	6	10.7	10.7	73.2
LONG TERM	9	16.1	16.1	89.3
NOT SURE	6	10.7	10.7	100.0
	-------	-------	-------	
Total	56	100.0	100.0	

Valid cases 56 Missing cases 0

(15). BENEFITS: RESPONSES TO QUESTION NO.16

Benefits		Count	% of Responses	% of Cases
COMMUNICATION		30	11.8	53.6
WORK PROCEDURES		52	20.5	92.9
EFFICIENCY		31	12.2	55.4
COMPETITIVENESS		26	0.2	46.4
TRACEABILITY		40	15.7	71.4
QUALITY		36	14.2	64.3
REDUCE ERROR		34	13.4	60.7
OTHERS		4	1.6	7.1
NOT YET SEEN	BFTI	1	0.4	1.8
		-------	-----	-----
Total responses		254	100.0	453.6

0 missing cases; 56 valid cases

(16). DRAWBACKS: RESPONSES TO QUESTION NO.18

Drawbacks	Count	% of Responses	% of Cases
FINANCIAL BURDEN	29	33.0	54.7
WORK BURDEN	40	45.5	75.5
BUREACRACY	13	14.8	24.5
NOT YET SEEN	6	6.8	11.3
	-------	-----	-----
Total responses	88	100.0	166.0

3 missing cases; 53 valid cases

(17). BENEFIT RANKING 1: RESPONSES TO QUESTION NO.17-1

Benefits	Count	Percent	Valid Percent	Cum Percent
COMMUNOCATION	1	1.8	1.9	1.9
WORK PROCEDURES	9	16.1	16.7	18.5
EFFICIENCY	7	12.5	13.0	31.5
COMPETITIVENESS	9	16.1	16.7	48.1
TRACEABILITY	5	8.9	9.3	57.4
QUALITY	11	19.6	20.4	77.8
REDUCE ERROR	8	14.3	14.8	92.6
OTHERS	4	7.1	7.4	100.0
MISSING	2	3.6	Missing	
Total	56	100.0	100.0	

Valid cases 54 Missing cases 2

(18). BENEFIT RANKING 2: RESPONSES TO QUESTION NO.17-2

Benefits	Count	Percent	Valid Percent	Cum Percent
COMMUNICATION	6	10.7	12.0	12.0
WORK PROCEDURES	11	19.6	22.0	34.0
EFFICIENCY	7	12.5	14.0	48.0
COMPETITIVENESS	5	8.9	10.0	58.0
TRACEABILITY	5	8.9	10.0	68.0
QUALITY	12	21.4	24.0	92.0
REDUCE ERROR	3	5.4	6.0	98.0
OTHERS	1	1.8	2.0	100.0
MISSING	6	10.7	Missing	
Total	56	100.0	100.0	

Valid cases 50 Missing cases 6

(19). BENEFIT RANKING 3: RESPONSES TO QUESTION NO.17-3

Benefits	Count	Percent	Valid Percent	Cum Percent
COMMUNICATION	9	16.1	16.1	16.1
WORK PROCEDURES	8	14.3	14.3	30.4
EFFICIENCY	5	8.9	8.9	39.3
COMPETITIVENESS	6	10.7	10.7	49.0
TRACEABILITY	9	16.1	16.1	65.1
QUALITY	5	8.9	8.9	74.0
REDUCE ERROR	5	8.9	8.9	87.5
MISSING	9	16.1	16.1	100.0
Total	56	100.0	100.0	

Valid cases 47 Missing cases 9

(20). CROSSTUBULATION 1: NUMBER OF EMPLOYEES (QUESTION NO.2)
by BUSINESS ACTIVITIES (QUESTION NO.1)

NOE	Count Row Pct Col Pct Tot Pct	BA S/D INST 1	S/D MANU 2	FIRE DO 3	SMOKE CO 4	OTHERS 5	Row Total
UNDER 10	1	3 100.0 12.0 5.4					3 5.4
10~29	2	8 80.0 32.0 14.3		1 10.0 9.1 1.8		1 10.0 11.1 1.8	10 17.9
30~49	3	4 40.0 16.0 7.1	1 10.0 11.1 1.8	3 30.0 27.3 5.4		2 20.0 22.2 3.6	10 17.9
50~99	4	1 8.3 4.0 1.8	4 33.3 44.4 7.1	5 41.7 45.5 8.9		2 16.7 22.2 3.6	12 21.4
100+	5	9 42.9 36.0 16.1	4 19.0 44.4 7.1	2 9.5 18.2 3.6	2 9.5 100.0 3.6	4 19.0 44.4 7.1	21 37.5
	Column Total	25 44.6	9 16.1	11 19.6	2 3.6	9 16.1	56 100.0

Number of Missing Observations: 0

(21). CROSSTABULATION 2: TURNOVER (QUESTION NO.3)
by BUSINESS ACTIVITIES (QUESTION NO.1)

TURNOVER	Count / Row Pct / Col Pct / Tot Pct	BA S/D INST 1	S/D MANU 2	FIRE DO 3	SMOKE CO 4	OTHERS 5	Row Total
	0	1 100.0 4.0 1.9					1 1.9
UNDER £1m	1	1 50.0 4.0 1.9		1 50.0 9.1 1.9			2 3.8
£1~2m	2	10 83.3 40.0 18.9		1 8.3 9.1 1.9		1 8.3 14.3 1.9	12 22.6
£2~5m	3	5 35.7 20.0 9.4	1 7.1 12.5 1.9	7 50.0 63.6 13.2		1 7.1 14.3 1.9	14 26.4
£5~10m	4	1 20.0 4.0 1.9	2 40.0 25.0 3.8			2 40.0 28.6 3.8	5 9.4
£10~50m	5	6 35.3 24.0 11.3	5 29.4 62.5 9.4	2 11.8 18.2 3.8	2 11.8 100.0 3.8	2 11.8 28.6 3.8	17 32.1
£50m+	6	1 50.0 4.0 1.9				1 50.0 14.3 1.9	2 3.8
	Column Total	25 47.2	8 15.1	11 20.8	2 3.8	7 13.2	53 100.0

Number of Missing Observations: 3

(22). CROSSTABULATION 3: COST-EFFECT (QUESTION NO.15)
by PRE-EXPERIENCE (QUESTION NO.6)

CE	Count Row Pct Col Pct Tot Pct	PRE-E NO 0	YES 1	Row Total
YES	1	13 37.1 43.3 23.2	22 62.9 84.6 39.3	35 62.5
NO	2	5 83.3 16.7 8.9	1 16.7 3.8 1.8	6 10.7
LONG TERM	3	6 66.7 20.0 10.7	3 33.3 11.5 5.4	9 16.1
NOT SURE	4	6 100.0 20.0 10.7		6 10.7
	Column Total	30 53.6	26 46.4	56 100.0

Number of Missing Observations: 0

(23). CROSSTABULATION 4: BENEFITS (QUESTION NO.16)
by PRE-EXPERIENCE (QUESTION NO.6)

BENEFITS	Count / Row pct / Col pct / Tab pct	PRE-E NO 0	YES 1	Row Total
COMMUNICATION	Count	17	13	30
	Row pct	56.7	43.3	53.6
	Col pct	56.7	50.0	
	Tab pct	30.4	23.2	
WORK PROCEDURES	Count	27	25	52
	Row pct	51.9	48.1	92.9
	Col pct	90.0	96.2	
	Tab pct	48.2	44.6	
EFFICIENCY	Count	17	14	31
	Row pct	54.8	45.2	55.4
	Col pct	56.7	53.8	
	Tab pct	30.4	25.0	
COMPETITIVENESS	Count	9	17	26
	Row pct	34.6	65.4	46.4
	Col pct	30.0	65.4	
	Tab pct	16.1	30.4	
TRACEABILITY	Count	22	18	40
	Row pct	55.0	45.0	71.4
	Col pct	73.3	69.2	
	Tab pct	39.3	32.1	
QUALITY	Count	17	19	36
	Row pct	47.2	52.8	64.3
	Col pct	56.7	73.1	
	Tab pct	30.4	33.9	
REDUCE ERROR	Count	16	18	34
	Row pct	47.1	52.9	60.7
	Col pct	53.3	69.2	
	Tab pct	28.6	32.1	
OTHERS	Count	2	2	4
	Row pct	50.0	50.0	7.1
	Col pct	6.7	7.7	
	Tab pct	3.6	3.6	
NOT YET SEEN	Count	1	0	1
	Row pct	100.0	.0	1.8
	Col pct	3.3	.0	
	Tab pct	1.8	.0	
Column Total		30	26	56
		53.6	46.4	100.0

Percents and totals based on respondents

56 valid cases; 0 missing cases

(24). CROSSTABULATION 5: DRAWBACK (QUESTION NO.18)
by PRE-EXPERIENCE (QUESTION NO.6)

DRAWBACK	Count / Row pct / Col pct / Tab pct	PRE-E NO 0	YES 1	Row Total
FINANCIAL BURDEN		18 62.1 62.1 34.0	11 37.9 45.8 20.8	29 54.7
WORK BURDEN		21 52.5 72.4 39.6	19 47.5 79.2 35.8	40 75.5
BUREACRACY		8 61.5 27.6 15.1	5 38.5 20.8 9.4	13 24.5
NOT YET SEEN		4 66.7 13.8 7.5	2 33.3 8.3 3.8	6 11.3
	Column Total	29 54.7	24 45.3	53 100.0

Percents and totals based on respondents

53 valid cases; 3 missing cases

(25). CROSSTABULATION 6: BUSINESS ACTIVITIES (QUESTION NO.1)
by EXTERNAL PRESSURE (QUESTION NO.8)

BA	Count / Row Pct / Col Pct / Tot Pct	EX-P NO 0	YES 1	Row Total
S/D INST	1	5 20.0 35.7 8.9	20 80.0 47.6 35.7	25 44.6
S/D MANU	2	4 44.4 28.6 7.1	5 55.6 11.9 8.9	9 16.1
FIRE DO	3	2 18.2 14.3 3.6	9 81.8 21.4 16.1	11 19.6
SMOKE CO	4		2 100.0 4.8 3.6	2 3.6
OTHERS	5	3 33.3 21.4 5.4	6 66.7 14.3 10.7	9 16.1
	Column Total	14 25.0	42 75.0	56 100.0

Number of Missing Observations: 0

(26). CROSSTABULATION 7: COST-EFFECT (QUESTION NO.15) by EXTERNAL PRESSURE

CE	Count / Row Pct / Col Pct / Tot Pct	EX-P NO 0	YES 1	Row Total
YES	1	11 31.4 78.6 19.6	24 68.6 57.1 42.9	35 62.5
NO	2		6 100.0 14.3 10.7	6 10.7
LONG TERM	3	3 33.3 21.4 5.4	6 66.7 14.3 10.7	9 16.1
NOT SURE	4		6 100.0 14.3 10.7	6 10.7
	Column Total	14 25.0	42 75.0	56 100.0

Number of Missing Observations: 0

(27). CROSSTABULATION 8: BENEFITS (QUESTION NO.16)
BY EXTERNAL PRESSURE (QUESTION NO.8)

EX-P Count Row pct Col pct Tab pct BENEFITS	NO 0	YES 1	Row Total
COMMUNICATION	11 36.7 78.6 19.6	19 63.3 45.2 33.9	30 53.6
WORK PROCEDURES	14 26.9 100.0 25.0	38 73.1 90.5 67.9	52 92.9
EFFICIENCY	8 25.8 57.1 14.3	23 74.2 54.8 41.1	31 55.4
COMPETITIVENESS	8 30.8 57.1 14.3	18 69.2 42.9 32.1	26 46.4
TRACEABILITY	10 25.0 71.4 17.9	30 75.0 71.4 53.6	40 71.4
QUALITY	12 33.3 85.7 21.4	24 66.7 57.1 42.9	36 64.3
REDUCE ERROR	10 29.4 71.4 17.9	24 70.6 57.1 42.9	34 60.7
OTHERS	0 .0 .0 .0	4 100.0 9.5 7.1	4 7.1
NOT YET SEEN	0 .0 .0 .0	1 100.0 2.4 1.8	1 1.8
Column Total	14 25.0	42 75.0	56 100.0

Percents and totals based on respondents

56 valid cases; 0 missing cases

(28). CROSSTABULATION 9: DRAWBACKS (QUESTION NO.18) BY EXTERNAL PRESSURE (QUESTION NO.8)

DRAWBACKS	EX-P: Count / Row pct / Col pct / Tab pct	NO 0	YES 1	Row Total
FINANCIAL BURDEN		5 17.2 35.7 9.4	24 82.8 61.5 45.3	29 54.7
WORK BURDEN		11 27.5 78.6 20.8	29 72.5 74.4 54.7	40 75.5
BUREACRACY		2 15.4 14.3 3.8	11 84.6 28.2 20.8	13 24.5
NOT YET SEEN		2 33.3 14.3 3.8	4 66.7 10.3 7.5	6 11.3
	Column Total	14 26.4	39 73.6	53 100.0

Percents and totals based on respondents

53 valid cases; 3 missing cases

(29). CROSSTABULATION 10: COST-EFFECT (QUESTION NO.15)
by BUSINESS ACTIVITIES (QUESTION NO.1)

CE	BA Count Row Pct Col Pct Tot Pct	S/D INST 1	S/D MANU 2	FIRE DO 3	SMOKE CO 4	OTHERS 5	Row Total
YES	1	12 34.3 48.0 21.4	7 20.0 77.8 12.5	5 14.3 45.5 8.9	2 5.7 100.0 3.6	9 25.7 100.0 16.1	35 62.5
NO	2	4 66.7 16.0 7.1		2 33.3 18.2 3.6			6 10.7
LONG TERM	3	6 66.7 24.0 10.7	1 11.1 11.1 1.8	2 22.2 18.2 3.6			9 16.1
NOT SURE	4	3 50.0 12.0 5.4	1 16.7 11.1 1.8	2 33.3 18.2 3.6			6 10.7
	Column Total	25 44.6	9 16.1	11 19.6	2 3.6	9 16.1	56 100.0

Number of Missing Observations: 0

(30). CROSSTABULATION 11: BENEFITS (QUESTION NO.16)
by BUSINESS ACTIVITIES (QUESTION NO.1)

BA

BENEFITS	Count / Row pct / Col pct / Tab pct	S/D INST 1	S/D MANU 2	FIRE DO 3	SMOKE CO 4	OTHERS 5	Row Total
COMMUNICATION	Count	10	5	7	1	7	30
	Row pct	33.3	16.7	23.3	3.3	23.3	53.6
	Col pct	40.0	55.6	63.6	50.0	77.8	
	Tab pct	17.9	8.9	12.5	1.8	12.5	
WORK PROCEDURES	Count	22	9	10	2	9	52
	Row pct	42.3	17.3	19.2	3.8	17.3	92.9
	Col pct	88.0	100.0	90.9	100.0	100.0	
	Tab pct	39.3	16.1	17.9	3.6	16.1	
EFFICIENCY	Count	12	6	6	1	6	31
	Row pct	38.7	19.4	19.4	3.2	19.4	55.4
	Col pct	48.0	66.7	54.5	50.0	66.7	
	Tab pct	21.4	10.7	10.7	1.8	10.7	
COMPETITIVENESS	Count	7	8	5	0	6	26
	Row pct	26.9	30.8	19.2	.0	23.1	46.4
	Col pct	28.0	88.9	45.5	.0	66.7	
	Tab pct	12.5	14.3	8.9	.0	10.7	
TRACEABILITY	Count	13	7	9	2	9	40
	Row pct	32.5	17.5	22.5	5.0	22.5	71.4
	Col pct	52.0	77.8	81.8	100.0	100.0	
	Tab pct	23.2	12.5	16.1	3.6	16.1	
QUALITY	Count	11	8	9	1	7	36
	Row pct	30.6	22.2	25.0	2.8	19.4	64.3
	Col pct	44.0	88.9	81.8	50.0	77.8	
	Tab pct	19.6	14.3	16.1	1.8	12.5	
REDUCE ERROR	Count	12	6	7	2	7	34
	Row pct	35.3	17.6	20.6	5.9	20.6	60.7
	Col pct	48.0	66.7	63.6	100.0	77.8	
	Tab pct	21.4	10.7	12.5	3.6	12.5	
OTHERS	Count	2	0	0	1	1	4
	Row pct	50.0	.0	.0	25.0	25.0	7.1
	Col pct	8.0	.0	.0	50.0	11.1	
	Tab pct	3.6	.0	.0	1.8	1.8	
NOT YET SEEN	Count	1	0	0	0	0	1
	Row pct	100.0	.0	.0	.0	.0	1.8
	Col pct	4.0	.0	.0	.0	.0	
	Tab pct	1.8	.0	.0	.0	.0	
Column Total		25	9	11	2	9	56
		44.6	16.1	19.6	3.6	16.1	100.0

Percents and totals based on respondents

56 valid cases; 0 missing cases

(31). CROSSTABULATION 12: DRAWBACKS (QUESTION NO.18)
BY BUSINESS ACTIVITIES (QUESTION NO.1)

DRAWBACKS	Count / Row pct / Col pct / Tab pct	BA: S/D INST 1	S/D MANU 2	FIRE DO 3	SMOKE 4	OTHERS 5	Row Total
FINANCIAL BURDEN	Count	13	3	9	0	4	29
	Row pct	44.8	10.3	31.0	.0	13.8	54.7
	Col pct	56.5	37.5	81.8	.0	44.4	
	Tab pct	24.5	5.7	17.0	.0	7.5	
WORK BURDEN	Count	18	6	8	0	8	40
	Row pct	45.0	15.0	20.0	.0	20.0	75.5
	Col pct	78.3	75.0	72.7	.0	88.9	
	Tab pct	34.0	11.3	15.1	.0	15.1	
BUREACRACY	Count	6	1	5	1	0	13
	Row pct	46.2	7.7	38.5	7.7	.0	24.5
	Col pct	26.1	12.5	45.5	50.0	.0	
	Tab pct	11.3	1.9	9.4	1.9	.0	
NOT YET SEEN	Count	3	2	0	1	0	6
	Row pct	50.0	33.3	.0	16.7	.0	11.3
	Col pct	13.0	25.0	.0	50.0	.0	
	Tab pct	5.7	3.8	.0	1.9	.0	
	Column Total	23	8	11	2	9	53
		43.4	15.1	20.8	3.8	17.0	100.0

Percents and totals based on respondents

53 valid cases; 3 missing cases

Appendix 3 Company Profile A

Company A was a subsidiary of the international construction group company. Its business activities covered design, installation, commissioning and maintenance of various kinds of fire safety systems as well as security and communication systems.

The company was headquarted in London and had six operational centres in London, Glasgow, Bilston (Staffordshire), Manchester, Bristol, and Wallsend. Its London operation centre employed about 80 staff. The annual turnover of the company in 1991 was about £20 million.

Based on its organizational structure, the company had a general quality system which covered all the quality activities in the company as a whole and in the London operation centre, and five individual quality systems for its regional centres. An independent quality manager was appointed in the London headquarters office, with the responsibility for the day-to-day operation of the quality activities in the company. There were no independent quality managers in the regional centres. The quality systems were looked after by the general managers of the regional centres.

The company first established a quality system in accordance with BS5750 Part 1 in its London office. The quality system covered the quality activities of the London operation centre. It gained a quality certificate from the British Standards Institution (BSI) in 1988. After the success of the quality system in the London operation centre, the company management decided to establish quality systems in each of its regional centres. Subsequently, the operation centre in Bilston set up the BS5750 quality system and obtained the quality certificate in 1989, and the Glasgow operation centre obtained the quality certificate to the BS5750 quality system in 1991, all from the BSI. The rest of the regional operation centres did not go for the BSI quality certification. Instead, all of its six operation centres registered their quality system with The Loss Prevention Certification Board (LPCB). The reason for this was that the LPCB emerged as a quality assurance certification body with significant influence in the fire protection industry.

Before the company set up its quality system, they had various kinds of written procedures and work instructions. But those documents were not organised in a systematic way. Responsibilities were not well defined, and there was no proper control over them. After the establishment of the BS5750 quality system, the company had formulated a series of comprehensive quality procedures which were compiled in a systematic way. Those procedures and documentation were not only constructed systematically but also well controlled. Lines of responsibilities and authorities were defined and an organisational structure for quality management was set up. This was seen as the major change that was brought about by the introduction of quality assurance.

Apart from the Quality Manual, the company also possessed other management manuals and documents: The General Management Manual, Technical Standards, Site Operation Manual, and Safety Manual.

The company were involved in various types of building projects. As the organisation of projects was concerned, the chief engineer and the quality manager both indicated that any forms of building procurement that were reviewed in Chapter 6.2 in this thesis could be used in the building projects. The clients of the company include architects, client's representatives, building contractors, management contractors, building services engineering contractors and other specialised fire safety engineering contractors. However, the chief engineer and the quality manager both pointed out that there were no major impacts on the quality practice of their project teams on matter what building procurement systems were used.

In the building projects, the company mainly worked as a subcontractor. The process that the company had involved in the building project usually went through the following stages: tendering and contracting--design and specification--installation--commissioning.

After the company won a contract, it set up a project team to prepare detailed design drawings and specifications. Communication and coordination were maintained closely with the client to who the company was contracted and with other parties of the building project. Installation work were carried out by subcontracted labours under the supervision of the project engineer. The company maintain a list of the subcontractors who had satisfied the company with their past performance.

Materials and components were either procured by the company from its suppliers, or supplied by the client according to the arrangement of the contract. The company also possessed a list of suppliers and maintained close relationships with them.

Internal quality audits were used to review the effectiveness of the quality system as well as to motivate employees to improve quality of their work. The quality manager had a detail schedule that defined when, where and how internal quality audits were to be carried out. Results of the internal quality audits were reported to the top management and, where appropriate, corrective actions were taken within specified time periods.

External quality audits were carried out every six months by the Loss Prevention Certification Board with who the quality system was registered.

Quality Circles were not introduced in the company. The quality manager suggested two reasons: (1) The company did not feel the need to introduce Quality Circles; (2) The business activities of the company were design and installation of fire safety systems in buildings. Quality Circles had not been proved to be effective in such activities.

The quality manager revealed that the introduction of the quality system brought a series of change to the company. These included change of behaviours as well as attitudes. Negative attitudes and resistance to change were seen among employees. Some employees did not see the need for the quality system. Some employees did not believe that the quality system would improve anything. They thought that the new quality assurance procedures were only to increase their work burden. Some senior staff were heard saying "What were wrong with our old system? Why should we bother to do these paper work?" Particularly, one senior staff complained by saying "I have been in this job for twenty years. Now you are telling me how to do it better!" Some design engineers were not quite positive with the quality system, because the quality system introduced "double check" procedures which require the drawings to be "double" checked and signed by two persons before they were issued.

To help staff to cope with the changes, seminars on the topics of quality assurance and BS5750 Quality Systems were organised by the quality manager. The quality manager also made frequent contacts with various personnel in the company to discuss the matters of quality. These discussions, as the quality manager believed, had worked effectively to clarify some misunderstanding on the concepts of quality assurance. Above all, internal quality audits, which were carried out regularly in all departments of the company, were regarded as the most effective method to increase quality awareness and to promote changes.

Quality assurance was considered being cost-effective in the company. However, the evaluation of the cost-effectiveness of the quality assurance programme was not made upon financial analysis. Quality costs were not practised by the company. The management of the company believe that the investment in quality assurance had produced meaningful results. The quality system was now operating effectively. It had brought the expected benefits to the company and was believed that it would continue to benefit the business in the future.

During the research, the quality manual and some of the quality procedures were studied in detail, which provided valuable information about quality operation in fire safety engineering companies.

Appendix 4 Company Profile B

Company B was one of the leading firms in the fire and security industry in the UK. Its business activities in the fire protection sector covered design, manufacture, installation and commissioning of a wide range of fire protection systems and equipment. Its factory and Technology Centre received the BS5750 Part 1 quality certificate in December 1986 from The BSI Quality Assurance and was among the first 1000 companies to be registered by BSI QA in the UK.

As the quality manager revealed that over the years the company had invested heavily in third party approval for its products and services to ensure the ultimate satisfaction of its customers. By 1992, the company had obtained over 900 product approvals from 41 international approvals bodies.

With the increasing demand for quality assurance from the customers, the insurers and the certification bodies, the company management recognised the need for the establishment of BS5750/ISO9000 Quality Systems in the company. In 1992, the company launched a comprehensive quality assurance programme. The aim was to achieved BS5750 Part 2 registration for each of its regional offices in Great Britain. The company had regional offices in Oldham, Birmingham, Brighton, Bristol, Cardiff, Edinburgh, Leeds, Liverpool, Newcastle upon Tyne, Nottingham, Plymouth and Reading.

An intensive plan was set up for the quality assurance programme with the high level of support from the top management. The Managing director pledged a personal commitment to the programme and chaired the Quality Management Team. An agreement was reached with three certification bodies to who the company's quality systems were to registered: the British Standards Institution Quality Assurance (BSI QA), the Loss Prevention Certification Board (LPCB) and the National Approval Council for Security Systems (NACOSS), to enable the quality assessment plan and schedule to be established.

A comprehensive plan was then set up and implemented to formulate the quality policy, quality manuals and procedures in each regional office as well as in the company headquarters. With the collective effort and the help from quality consultants from all three certification bodies, quality systems were established in accordance with the requirement of BS5750/ISO9000.

Quality training was carried out throughout the company. Each regional office appointed a Quality Representative who attended an intensive 4-day Lead Assessor Course and examination. A training programme was developed for engineers and supervisors to cover the requirement of the relevant British Standards for the installation of fire and security systems. Seminars and short courses were also organised to carry out the quality education aimed at changing employee's attitudes on quality and promoting a company-wide quality awareness.

After the establishment of the quality systems in all regional offices, a "Quality Assessment Tour" was organised according to the assessment plan and schedule. During the "Quality Assessment Tour", the quality assessors from all the three certification bodies mentioned above carried out a joint quality assessment to the quality systems at the regional offices and to the installation that were completed by the company.

The quality assurance programme was considered as highly successful and cost-effective. The quality manager suggested that the quality assurance programme involved much more than conforming to a list of off-the-shelf requirements. It set out to achieve a complete re-thinking of the working practices in the company. In fact, the overall investment in people and processes far outweighed the fees paid to the quality consultancy and the quality certification. The thorough review of the working practices that was carried out through the process of developing the quality systems enabled the company to improve the efficiency of the business operation. As a result, it reduced response time and false alarm incidents and enabled the company to ensure the highest possible level of service to the customers. In addition, the quality assurance programme not only set up a comprehensive organisation structure for quality management within the company but also created a company-wide quality culture which is essential for the achievement of "total quality".

Appendix 5 Company Profile C

Company C was an automatic sprinkler systems installer with about 30 employees and an annual turnover between £1.5~2 millions. Its business activities involved design, installation, commissioning and maintenance of automatic sprinkler systems.

The company had a simple organization structure that consisted of a design office, a small workshop and a team of site workers. There were no formal departments, such as department of marketing or quality assurance, in the company. One person could have various responsibilities. Mr M, whose formal position was the Company Secretary, was in charge of finance, daily business operation as well as quality assurance.

The company possessed a quality system in accordance with BS5750 Part 1. The quality system was certified by the Loss Prevention Certification Board (LPCB) in October 1991.

The reason for the company to set up the quality system was that it was required by the LPCB's new quality certification scheme. Mr M revealed that if it had not been mandated by LPCB's new quality certification scheme, the company would not have introduced quality assurance at this stage. The company had not seen the internal need for the quality system to improve its quality management practice. However, if the company could not get the quality approval from LPBC, it would be very difficult for it to operate its business in the highly competitive market.

A quality management consulting firm was employed to help the company to develop the quality system. But the company only learned from the consultant about the general aspects of quality assurance and the quality system. Mr M and the managing director prepared all the documents required by the quality system.

The quality system in the company included two parts:

Part A: The Quality Manual, which was the overview description and statements of the quality assurance activities in the company;

Part B: The Quality Procedures, which gave detailed guides and specifications for every operation to be carried out under the requirement of BS5750.

The documentation of the quality system was established in a formal way in accordance with the requirements of BS5750. However, the daily business operation in the company was rather informal. Because of its small size, informal communication was thought to be more efficient. Therefore, the formal quality system had both positive and negative effects in the company:

The positive effect was that the quality system formalised the communication flow in the company in terms of quality control. It increased traceability of work and the sense of responsibility among staff.

The negative effect was that it created extra work and to some extent affected the efficiency. It also increased the company's financial burden. The quality manager revealed that to his company the operation of a certified quality system was costly. He had not seen much benefits from the quality system but believed that it would be beneficial and cost-effective in the future.

Before the quality system was to be implemented, seminars were held in the company and copies of the Quality Manual and Quality Procedures were distributed to all relevant staff. However there was no regular educational programme to keep the staff being aware of the current quality issues.

Internal quality auditing was regarded as the measure by which the effectiveness of quality system was evaluated and by which staff were motivated. No other evaluation methods such as quality costs were used to assess the cost-effectiveness of the quality assurance programme and the quality system. The company did keep records of field calls and analyse the quality problems in each cases. But field call records were not used for monitoring the improvement of quality.

Some negative attitudes to quality assurance were shown among some staff at the beginning of the quality assurance programme. Such attitudes were changed eventually. The quality manager spent a great deal efforts to talk to staff and to convince them the need for quality assurance in the company.

The company was involved in various kinds of building projects. The organisation of the project teams varied from project to project. But the organisation processes were not changed in general, which included several major steps: tendering, design and specification, procurement of material, installation and commissioning. Quality plans were issued to guide the quality assurance activities of the project teams. Each project had a completed quality plan. However, the quality manager suggested that the co-ordination between his company and other parties of the project, such as the main contractor, building services subcontractor and other fire safety engineering subcontractors, sometimes was still a problem. This should be addressed in the quality plans.

Appendix 6 Company Profile D

Company D was a private-owned small business with only ten staff. Its business activities involved design, installation and maintenance of sprinkler systems. Its organization structure was rather simple and informal. In the company office, there were six staff: the managing director, the operation manager, the financial manager, a secretary, and two design engineer. In addition, there were two technicians and two fitters working on site. The company used subcontract labours to carry out a large proportion of site installation work for the company.

Mr J, the Managing Director, who bought the company a few years ago, takes the overall responsibility for quality. He attended a BS5750 seminar organised by a quality management consultant company but did not went further with the consultant, because employing a quality consultant was thought to cost too much to his company. He prepared the document of the quality system on his own. The operation manager, Mr B, was appointed as the quality manager late.

The company possessed a quality system in accordance with BS5750 Part 1, which was certified by LPCB in October 1991. The top management of the company felt strongly that they were pushed to quality assurance by the pressure from LPCB's new quality certification scheme.

According to the managing director and the quality manager, quality assurance did not bring immediate profit to the company. On the contrary it cost a considerable sum of money for quality certification. However, since it was mandated by LPCB, the company had to get it. Otherwise, it would be very difficult for the company to do business. The company wanted its name to be appeared in the "LPC's List of Approved Products and Services", which was an authoritative guide for the buyers of fire protection products and services, published by the Loss Prevention Council. The clients might not require the company possessing a quality certificate as a condition for contract, but they did select products and services from the LPC's List.

It was revealed that the top management of the company had rather a negative attitude to quality assurance. With such an attitude, it was in doubt whether the quality system in the company would operated effectively. During the most recent quality audit conducted by the certification body LPCB, a considerable number of non-conformance had been found in the quality system. Although corrective actions were completed to satisfy the requirement of the LPCB, the quality manager had many disagreement with these requirements. In the interview, the quality manager showed the researcher the LPCB's quality audit report and argued that some requirements in the report made no sense to improve quality but increased extra work burden.

The company was a new and small business, struggling for its survival and development. Financial problems and immediate profits were likely to have priority over the issue of quality, although it was understood that better quality would increase marketing strength. The quality manager revealed that the company was facing some difficulties. The management was more concerned about making profits than quality assurance. He stated that if it had not been mandated by LPCB, the company would not have established the quality system. The negative attitudes of the company's management towards quality assurance raised a question to the management commitment to quality. Although the company possessed a certified quality system, it was questionable that whether the company had achieved necessary leadership and commitment that were essential to quality assurance.

Because of the small size of the company, business operation within the company were kept simple and easy. Lines of communication were short and simple, and work relationships tended to be close and informal. People were used to talk face to face and avoided any unnecessary paper work. However, the quality system of the company, which was established in accordance with BS5750 Part 1, were no less simple that the quality system of a larger firm.

The company was involved in various kinds of building construction and maintenance projects. However, the types of building project did not have significant influence on the business operation process of the company. The company usually started involving in a project by preparing documents for tender. When the company won the contract, the design drawings and specifications were prepared in accordance with the client's requirement. The installation work were carried out by the site staff and subcontracted labour under the supervision of technicians and design engineers, while material and components were procured from the suppliers according to the specifications. The company had a list of suppliers and a list of subcontracted labour, who had satisfied the company with their past performance.

Appendix 7 Company Profile E

Company E was a specialised automatic sprinkler systems installer. It employed 17 staff and had an approximate annual turnover of £2 million. Its major business activities involved design, installation and maintenance of automatic sprinkler systems.

As a small company, it did not have formal divisional or departmental structure. However, compared with Company C and Company D, the responsibilities of managers in Company E were more specialised. The company appointed the independent quality manager, operation manager, sales manager, purchase manager and small work manager, each of them working in a specialised area of business. Technical staff of design engineers and technicians were working closely with the management and were assigned some management job when a contract or project was involved.

The company also had a small store for purchased materials and components. Site installation work were carried out mainly by subcontract workers under the supervision of the company's engineers and technicians.

The company set up its quality system in accordance with BS5750 Part 1 in early 1991, with the help of a quality management consulting firm, and gained the quality certificate from the Loss Prevention Certificate Board (LPCB) six months later. The quality manager and the managing director of the company attended a training course offered by the quality consulting firm on the subject of quality assurance and BS5750. The quality consultant also provided some in-house training for the company's staff for the operation of the quality system.

The quality manager suggested that the company was mandated to install the BS5750 quality system by the LPCB. The company had been a 'LPCB approved sprinkler systems installer', with its name listed in the "LPC's List of Approved Products and Services". However, since the PLCB was to replace the existing quality approval scheme with its new quality certification scheme in which the BS5750 quality system become a mandated requirement, the company felt that they had no choice but to install the quality system. The quality manager said that without the LPCB's approval the company would not be able to keep its market.

The company had no previous experience of quality control and quality management. The quality system brought many new operation procedures into the company. There were various kinds of responses to the changes. Generally, the new quality assurance procedures were welcomed by staff at all levels. Particularly, the formal document control introduced by the quality system was considered to be very useful. It increased the traceability of work and the sense of responsibility among the staff. However, the staff as well as the management of the company was not very confident on the effectiveness of the quality system to achieve high quality.

It was believed that the quality procedures would become a part of the daily business operation once the staff had got used to them, and the quality system would become more effective in the future.

Negative attitudes to quality assurance were seen among some senior staff when the new quality procedures were introduced. These were mainly due to lack of trust in the quality system. Some considered that the quality procedures increased extra work burden but added nothing to the business performance. Some management personnel thought that the quality certification cost too much to the company. They argued that the LPCB's mandated requirement of BS5750 was too radical and put too much pressure to small firms like theirs.

Although the quality manager also had the view that the LPCB's requirement of BS5750 was too radical, he believed that quality assurance was the trend in future business practice and would be required by the clients in the future. Therefore the current investment in quality assurance would be returned in the future business. In the meantime, the quality manager agreed that there needed efforts to increase the staff's quality awareness and this could be done by persuasion and education. A quality-centred organisational culture would make the quality assurance more efficient and would bring long-term profits to the company.

In building projects, the company was contracted to various kinds of professional firms according to the procurement arrangement of the projects. In most cases, the contracts came from building services engineering companies, management contractors and project managers.

Subcontracted labours carried out most of the installation work on the building sites. Subcontracted labour control therefore was an important part of the quality assurance. The company retained a list of approved labour contractors who were assessed by the company by their past performance and experience.

The company usually offer one year warranty for its work and kept the records of field calls during that period. However, some field calls turned out to be the client's mistake and therefore could not be used for the assessment of the quality of their work. The company was confident on the quality of the work they were currently offering to the clients.

Appendix 8 Company Profile F

Company F was a small company specialised in design and installation of automatic sprinkler systems. It was owned by a building services engineering company and had only eight staff.

The company developed a quality system complying to BS5750 Part 1 in January 1991. In November 1991, the quality system was certified by the Loss Prevention Certification Board (LPCB).

The company had been contracted to design and install automatic sprinkler systems in various building projects. Its clients included architects, general building contractors, management contractors, building services engineering contractors and other building professionals.

While the company decided to introduce BS5750 into its organisation, it did not feel pressure from its clients but perceived the pressure from insurers and the certification body LPCB. However, the quality manager recalled that the reasons for the company to adopting quality assurance was not merely the external pressure that was perceived. The company management also saw the possession of a certified BS5750 quality system would increase its market strength.

They did not have any formal quality control or quality management procedures before BS5750 was introduced. The operation of the formal quality procedures were new to all its staff. As such a small organisation with engineering design as its major business activity, staff were used to work in an informal way to limit any 'unnecessary' paper work. Therefore, the formal paper work required by the quality system was not treated seriously by some of the staff. These was changed after several months of operation of the quality system. To change these negative attitudes, the quality manager made his best effort to persuade the staff that the formal quality procedures could bring benefits to the business.

The operation of quality system in the company did to some extent increase extra work burden and reduced efficiency. But this was only a short term effect. After several months, staff had got used to the procedures and the situation was improved. The quality system began to bring benefits to the company. The company felt that the quality system increased its marketing strength. It also increased traceability of work and reduce errors. Particularly, as the quality manager suggested that BS5750 brought into the company a more efficient control on contract variations and thus made contracts more profitable.

Quality certification and operation of the quality system were considered to be costly by the company. The quality manager suggested that it was difficult to tell if the quality system was cost-effective or not at this stage, since the benefits of the quality system were difficult to be measured in financial term. However, it was believed that it would be cost-effective in the future as the quality system would eventually increase the efficiency of work in the company and reduce the costs of error.

Appendix 9 Company Profile G

Company G was a small manufacturer specialised in fire and industrial doors and shutters. The company had ten staff.

The company's major product, fire break rolling shutters, had been approved by the Loss Prevention Certification Board for many years, and was listed in the "LPC's List of Approved Products and Services" published by the Loss Prevention Council. This list was an authoritative guide to the specifiers, contractors and purchasers in fire protection products and services.

In 1991, the Loss Prevention Certification Board launched a new Product Conformity Certification Scheme for fire break doors and shutters. This new Scheme was expected to replace the existing Quality Approval Scheme. The Certification Scheme required product test to the appropriate standards as well as assessment audit of the manufacturer's quality management system to BS5750 Part 1 or 2. This became the direct motivator for the company to install the BS5750 quality system.

Mr B, who was the production manager of the company, was appointed to be responsible for establishing the quality system. He attended a BS5750 training course and prepared the documentation of the quality system. In December 1991, the quality system was certified by the LPCB.

The production activities in the company were relatively simple. Quality control activities were also very basic. The introduction of the quality system brought in a considerable amount of paper work to the staff. Staff in the company were not used to this kind of paper work and therefore were not very positive with the quality procedures. However, since they were the requirements of the quality system, Mr B felt that he had the responsibility to ask staff to follow the quality procedures. He carried out the internal quality audits once every month to review the quality system and to ensure that the quality procedures were implemented effectively.

The costs of quality certification was considered as an financial burden to the company. However, the company had to maintain the quality certificate and to maintain its entry in the LPC's List. Otherwise, it would be difficult for the company to market its products. Mr B admitted that the company adopted quality assurance mainly for the reason of marketing. He did not seen any other benefits of the quality system at this stage. He complained that the LPCB's new quality certification scheme produced too much pressure to small companies like his.

Although the company was not very positive with quality assurance, quality of the products was regarded as important to the business. Any customer's complaints to the company on its product quality was treated seriously. The company maintained quick responses to any customer's complaints. All complaints from the customers and the actions taken by the company were documented carefully even before the company had the quality system.

Mr B hoped that the quality system would bring to the company more benefits and would be cost-effective in the future.

Appendix 10   Company Profile H

Company H was a subsidiary of a Japanese company which is headquartered in Tokyo. Its Japanese parent company in Tokyo was established in 1954 and had grown into one of Japan's major enterprises specialising in producing fire detection, fire alarm and fire extinguishing systems. Company H was opened in June 1972, and its production was concentrated mainly on automatic fire detection equipment. At the beginning, the company made just one type of smoke detectors as a kit from Japan. It gradually developed from buying nearly all the components from Japan to purchasing most of the material in UK, and developed from a kit assembly company to a company with independent capacities of design and manufacture. The company now had 90 employees with an annual turnover of £20~30 million.

Quality had been the attention of the company for a long time. As the company claimed, its products were relied upon internationally for the protection of life and property and there was no compromise where quality control was concerned. Every single detector was individually subjected to a complex test procedure. All new product designs must first pass rigorous Japanese Government tests before they were subjected for approval by other official bodies such as V.D.S. (Germany), UL (USA), and LPCB (UK). The company believed that success in gaining approvals from such bodies resulted in their specification by a wide range of clients including architects, consultants, contracting engineers and public authorities.

The company had introduced also some Japanese methods of quality control for its production process control. While the workforce was predominantly British, the company had a Japanese managing director and several Japanese technical advisors. The technical advisors were involved actively in quality assurance and quality control.

The quality system was first brought in by the Japanese management when the company was started. In 1979, the quality manager Mr B, who was then the production manager and the quality controller, was particularly interested in the BS5750 Quality Systems. He attended a seminar introducing BS5750, which was given by the British Standards Institution. He was keen to introduce the BS5750 Quality Systems to the company. But there was not the motivation for the company to introduce it at that time.

One of the motivators for the company to introduce BS5750 Quality Systems, as the quality manager recalled, was the launch of the LPCB's new Quality Certification Scheme which required the possession of a Quality System complying with BS5750. Also, the company's market was not only the UK, but some other countries in Europe, Middle East, and other parts of the world. A certified BS5750 Quality System, which is identical to ISO9000, would increase the company's marketing strength.

The company did not have any Quality Circles, nor was the method of Quality Costs applied in the company. This was because the management of the company had not felt the need for doing so.

The company manufactured and supplied smoke detectors and control panels. It did not offer installation services for fire detection systems. Customers of the company who were usually business services engineering firms completed the installation. The company provided technical support to its customers through its technical sales staff. It was the responsibility of the technical sales staff to give rapid responses to any problems and requirements from the customers. When any customers had any special requirements for the products, usually for the control panels, the company could make special design to meet the customer's requirements.

The company remained constant relationships with its material and component suppliers that it had had for many years. The assessment of the supplier's capability was established on what the quality manager called 'satisfactory past experience', which meant the confidence in the quality of supplied material and component was built through long-term co-operation. Every supplier had been given a written notification specifying the requirements of the company. When the company needed a new supplier, the company would examine the supplier's quality management practice and performance records. If necessary, a visit would be made to the supplier's organisation to assess its capability. In the current practice it was not a necessary requirement for the suppliers to possess BS5750 Quality Systems. However, the company was now pushing its suppliers towards the direction, as the quality manager said. The possession of BS5750 Quality Systems would be a part of the purchase requirements in the future.

The company had not operated a formal Total Quality Management programme. But the quality manager suggested that the ideas of 'total quality' had been in practice in the company. The company always emphasised quality as the centre of its corporate culture. Quality awareness had been established through the application of various quality control techniques, introduction and implementation of the BS5750 quality system and a series of quality-related staff training programmes.

Appendix 11 Company Profile I

Company I was one of the leading manufacturers of automatic fire detectors in the UK. It employed about 100 staff in the factory and produced an annual turnover of about £20 million. The company had a strong performance on export and had agents and distributors in many countries.

The company started its quality assurance programme in December 1986 with the introduction of a quality system that was in accordance with BS5750 Part 1. The quality system was registered with the BSI Quality Assurance Service in September 1987.

The company did not feel pressure from outside demanding quality assurance. Quality assurance was considered by the company management as a strategic approach for quality improvement and for business development.

With the increase of quality awareness among its clients, the company perceived an increasing demand for a certified quality system. In the past a few years, the company received a increasing number of inquiries of its quality assurance status, including questionnaires and visits from its current and potential clients in association with quality assurance practices.

Apart from the quality certificate that the company gained from the BSI Quality Assurance Services, the company also held a quality certificate from the Loss Prevention Certification Board (LPCB). The LPCB launched a new Quality Certification Scheme and was becoming more and more influential in the fire detection sector of the industry. The company decided that a quality certificate to its quality system from the LPCB would make the clients more confident on its product quality. It registered its quality system successfully with the LPCB in August 1990.

The company therefore held quality certificates to its quality system from two certification bodies. The company believed that it was necessary to retain these two quality certificates for its domestic as well as overseas market. However, under the requirements of the certification schemes, both certification bodies conducted independent quality audits to the quality system in an approximate interval of six months. This produced extra work burden as well as financial burden to the company. It was hoped that the BSI and LPCB would reach an agreement of mutual recognition that would remit the unnecessary double quality audits.

The company also gained quality approvals and quality certificates from many other countries as export was an important part of the business operation in the company. The Managing Director revealed that the company had spent a great deal of money and efforts on quality approvals. However, he believed that the company's investment in quality assurance was rewarded by its market performance.

The company was a part of the large company who were quality approved to DEF 05-21, a military standard which embraced similar systematic quality management as BS5750/ISO9000 Quality Systems. In 1980 when the company became independent, though the quality approval did not extend to the new company, most of the systematic quality controls were maintained, in particular, the documentation control such as drawings schedules, test procedures and production operation sheets. This made the work of establishing the quality system easier. The quality manager suggested that the company did not experience major changes brought about by the introduction of BS5750.

The quality system was prepared by the quality manager with the help of a consultant from the BSI. However, the quality manager obtained a great deal of support from the company's top management. The top management understood that their commitment to quality was essential to the achievement of quality assurance. Quality assurance was regarded as one of the marketing strategies.

The company was considering the introduction of a Total Quality Management programme in a few years time. The quality manager suggested that the company held a tradition of emphasising the value of quality and had an established quality climate in the company.

Apart from the quality assurance programme, the company operated an employee management participating programme which was similar to the Quality Circles. Management participating groups were organised among employees on a voluntary basis. Various activities were organised by these groups, ranging from trouble-shooting to voluntary labour work. When the researcher was visiting the company, it happened that one of the group was cleaning the window glasses during lunch time.

Quality assurance in the company was effective, as so the quality manager assessed. However, no financial analysis was made to evaluate the cost-effectiveness of the quality system. The method of quality costs was not used. Products and components were tested and inspected throughout the production process. Test and inspection were not carried out statistically but on a 100% rate. Records of the inspection results were kept and analysed for monitoring the production process and quality of the products.

As a manufacturer, the company did not involve in building projects directly. Their products were usually installed by the customers. However, the company provided extensive technical support to the customers. The technical sales division of the company not only gave advice on how their products could be used, but also responded to any technical problems that were raised during and after installation. This service was regarded by the company as an essential part of the quality assurance.

Also as a part of its quality assurance practice, the company maintained a close relationship with its suppliers who provided raw material and components to the company. Most suppliers had been with the company for quite a long time. Although the company did not require all its suppliers to possess a BS5750 Quality System, the supplier's quality performance were reviewed regularly. The quality manager of the company or her assistants visited the supplier's factories on a regular basis to inspect the supplier's quality management practice.

Appendix 12 Company Profile J

Company J was specialised in manufacturing fire detection equipment and was one of the leading companies in this field in the UK. With a number of about 100 employees, the company produced a turnover of £24 million in 1992.

The company set up its quality system in accordance with BS5750 part 1 in August 1991. The quality system was approved by the Loss Prevention Certification Board (LPCB) in May 1992.

Prior to the establishment of the BS5750 quality system, the company had a series of measures of quality control, including Statistical Process Control and various quality control procedures. But these were not organised and managed in the systematic way. The company-wide quality consciousness was not established. The Quality Department was seen as the only department that was responsible for quality control. The company's products were quality approved by the LPCB and listed in the "LPC's List of Approved products and services".

A direct motivator to the company's quality assurance programme was the development of the new quality certification scheme by the LPCB. In the traditional quality approval scheme of the LPCB, there was no requirement to the company's quality system. However, in the new quality certification scheme, which was to replace the existing quality approval scheme in the near future, possession of a BS5750 quality system became the mandated requirement. Therefore, the company management decided to install a BS5750 quality system in the company to meet the LPCB's requirement.

However, to meet the requirement of the LPCB was not the only motive that had driven the company's quality assurance plan. The company management was aware of the wider recognition of the BS5750/ISO9000 Quality Systems in the market. The company received an increasing number of inquiries from its clients about its quality assurance status and practices. To remain the company's leading position in the market, it was necessary to have a certified quality system.

The quality assurance programme was also considered as a major step to improve the quality management practice and to increase the employees quality awareness in the company. As a result, comprehensive quality assurance procedures and work instructions were established, which formed a special feature of the quality system.

The quality system was structured at five levels:

Level 1: Quality Manual
Level 2: Process Procedures
Level 3: Activity Procedures
Level 4: Work Instructions
Level 5: Support Documentation

In the Quality Manual, it stated: "It is the policy of the company to provide products and services that fully meet all reasonable quality expectation of customers. ...Quality achievement is the responsibility of all employees of the company from the Managing Director down, to ensure that actions taken secure the required quality standards."

The Process Procedures and the Activity Procedures identified the processes and activities of the business operation in the company, and specified the standard procedures to be followed in the processes and activities. Quality operations were organised in a dynamic way with the focus on production processes and activities. This was aimed at enhancing the co-ordination between departments.

Also included in the quality system was a collection of all relevant product specifications, standards, and codes of practice which formed a set of support documentation to the quality operations.

As a leading company in the fire detection industry, the company was actively involved in legislation activities. The quality manager, quality engineers and technical personnel were acting as members of various working groups of the legislation institutions such as the International Standards Organisation (ISO) and the British Standards Institution (BSI), and trade associations such as the British Fire Protection Systems Association (BFPSA).

Internal quality audits were systematically planned and carried out to determine the effectiveness of the quality system. They were also used as a measure to motivate the employees to implement the quality system effectively.

Training on quality control and quality assurance were organised by the Quality Assurance Department through various seminars and group meetings with focused topics on quality.

The company management saw the quality assurance programme as cost-effective. But this was evaluated on the basis that the investment in the quality assurance programme had achieved its predetermined goals. The method of quality costs was not used, mainly because the management did not feel the need for doing so.

The implementation of the quality assurance programme had brought into the company a series of changes. These included changes in the organisation structure as well as in human behaviour. With the establishment of the quality system, the company set up a formal structure for the organisation and management of the quality operations. According to the quality manager, the company had also achieved a remarkable quality awareness among its employees through the implementation of the quality assurance programme. At the beginning of the quality assurance programme, there were some reluctance and negative attitudes among some employees. But these had disappeared as the quality system and the quality operation procedures were adopted into practice. The company was on its way to establish a company-wide quality culture with everybody involving in the operation of the quality system. He hoped that this would lead to the formal introduction of a Total Quality Management Programme in the near future, although such a programme had not currently been scheduled.

Appendix 13 Company Profile K

Wormald Ansul (UK) Ltd was a subsidiary of a leading international company in the fire protection industry. It was specialised in manufacturing sprinkler systems and components. It had about 90 employees working in the factory.

The company started its quality assurance programme in 1988, by establishing a quality system in accordance with the requirements of BS5750 Part 1. The quality system was certified by the Loss Prevention Certification Board (LPCB) in April 1990.

Prior to attaining quality certificate to the BS5750 quality system, the company was approved by the Ministry of Defence in accordance to the quality assurance standard of A.Q.Q.P.1 Edition 3. The approval lapsed in October 1989 because the A.Q.A.P. Series of Standards were incorporated into the requirement of BS5750 Quality Systems. The company also had the quality approval from the FOC, the predecessor of the LPCB, for a long time. However, the requirement of quality systems was not included in the quality approval scheme.

While the company was developing its quality assurance programme, it perceived the pressure from its clients and business rivals. According to the quality manager, the company frequently received postal questionnaires and visits from the clients inquiring about the quality assurance practice of the company. Some business rivals of the company had established quality systems and had obtained quality certificates from authoritative certification bodies. The company therefore felt that a certified quality system was necessary for remaining the company's leading position in the market. The company also perceived pressure from the Loss Prevention Certification Board who developed a new quality certification scheme in which the BS5750 Quality Systems was a mandated requirement.

During the process that the quality system was developed and implemented, the quality manager of the company played the major role to initiate and manage the changes that were brought about by the introduction of the new quality system. The quality manager attended a seminar on BS5750 Quality Systems organised by the BSI and prepared the documentation for the quality system.

The quality system was established in accordance with the requirements of BS5750 Part 1. It consisted of two parts: the Quality Manual and the Quality Procedures. While developing the quality system, the quality manager had a series of intensive discussion with people at various levels and in various divisions, to decide how the operation procedures could fit in with the requirements of BS5750. The quality manager revealed that employees responded to the new quality system quite positively. The changes that were brought about by the quality system were implemented smoothly. After all, there were no major changes involved since the company had a similar system prior to the BS5750 quality system.

The company had experienced many benefits from the implementation of quality assurance. These included increase of marketing strength, improvement of communication and improvement of quality. However, the quality system to some extent increased financial burden and produced extra load of work.

The quality system was believed to be cost-effective. However, it was not concluded from cost-benefit analysis. The method of quality costs was not applied for the evaluation of the effectiveness of the quality system. The quality manager and the company's management believed that the investment in the quality system was returned by the increase of the competitiveness in the market and subsequently by the increase of sales. The company's export was increased in the past a few years. The quality manager suggested that the recognition of ISO9000/BS5750 Quality Systems certainly increased the marketing strength of the company. Apart from the quality certification by the LPCB in the UK, the company also obtained quality approvals and quality certificates from a number of countries in other part of the world.

Statistical quality control was not used in the factory. All products and components were tested and inspected according to the specifications. No quality circles existed in the company because there was no need for them, as the quality manager explained.

The company had considered to introduce a Total Quality Management Programme in the next a few years. Through the operation of the quality system, the company had improved the quality awareness of its employees. However, it would still take some time and effort to promote a company-wide quality culture.

Appendix 14 Company Profile L

Company L was the UK subsidiary of an American based international group company. Its business activities involved in design, manufacture, installation, commissioning of building control systems and fire detection systems.

The company launched its quality assurance programme in march 1985. The management of the company decided to set up a quality system in accordance with the requirements of BS5750 Part 1 and to registered it with an authoritative quality certification body. Unlike some companies who started quality assurance programmes under certain external pressure, this company saw quality assurance as a method to improve the company's quality management practice and therefore to improve the customer's satisfaction. It was also hoped that the recognition of the certified quality system by the customers would increase the employee's pride of work and increased profitability.

The quality manager was sent to a short course provided by a quality consulting firm, and a quality consultant was invited to the company to give a seminar to the senior management of the company. The quality manager then held a number of meetings and seminars with staff of the company at various levels. The quality manager and the quality consultant worked together in developing the quality manual and quality procedures.

In October 1986, the quality system gained a quality certificate from the LRQA who is an authoritative quality certification body operating in the building services industry. The company has also registered with the Loss Prevention Ccertification Board (LPCB) who was getting more and more influence in the market sector of fire detection equipment.

The company had no formal quality management procedures prior to the establishment of the BS5750 quality system, although certain quality control methods of testing and inspection were used in its manufacturing division. Difficulties in implementing the quality system were seen at the beginning. however, these were overcome eventually. After years of operation, the company have seen many benefits from the quality system and saw no drawbacks of the quality system that were claimed by some other companies. At the early stage of the quality assurance programme, the introduction of the quality system was thought by some employees as increasing extra work burden. But this was no longer the case, for people were used to the operation of the quality system. The quality procedures were incorporated into the day to day business practice.

The quality manager suggested that the real commitment to quality from the top management was essential to the achievement of quality. The company's top management had given a strong support to the quality manager and the quality assurance activities in the company. Without such support the quality assurance programme would not have been as effective as it was.

The quality manager was confident that the quality assurance programme in his company was cost-effective. Operation of the quality system did cost a considerable amount of money, especially when it was registered with two certification bodies. However, he said that the quality was operating very effectively now and had brought many benefits to the company. The company now frequently received questionnaires and visits from its clients and potential clients in association with quality assurance. The certified quality system gave clients confidence on quality of the products and services provided by the company.

However, the company did not use the method of quality costs to assess the cost-effectiveness of its quality programme and the quality system, because the method was not applicable to the business operation of the company which involved design and installation activities in building projects.

Customer's complaints were recorded and analysed for monitoring quality of products and services and for evaluating the improvement of quality.

Internal quality audits were used as the major method to assess the effectiveness of the quality system. Numbers of nonconformance found in quality audits were compared over time to evaluate the progress of the quality assurance programme. The quality audits revealed a considerable number of nonconformance in the first a couple of years while the quality system was just put into operation. These were decreased steadily as the operation of the quality system became a part of the normal business operation in the company.

Appendix 15 Company Profile M

Compamy M was a major producer of ventilation and smoke control equipment in the UK. It was specialised in heating, ventilation and smoke control systems. It had about 500 staff working in its headquarters and the factory in UK, and operated its business activities world-wide through its regional offices, distributors and joint ventures in continental Europe, Middle East, Far East and the Pacific region.

The company started planning for quality assurance in July 1985. The quality assurance programme was aimed at adopting the BS5750 Quality System into the company's quality management. This had two major purposes.

The first purpose was to improve the company's quality management practice by establishing the quality management system. The company had some quality control procedures in its factory. But those were not systematic and only covered some parts of manufacturing activities. The quality assurance programme was then aimed at establishing systematic quality management structure and procedures that covered all the areas of business operation in the company.

The second purpose was to improve marketing strength through registered the company's quality system with the authoritative quality certification body, the British Standards Institution (BSI). It was understood that a certified quality system complying to BS5750/ISO9000 would increase the customer's confidence on the quality of the products and services supplied by the company.

After preparation of more than one year, the quality system was certified by the BSI in December 1986.

The production process and technology were relatively simple in the factory. Many tests and inspection involved in the production were rather basic. However, quality control had always been a major concern of the management. Tests and inspection were carried out at various stages throughout the production process.

When they were major changes in the design of the ventilation and smoke control systems, they were subjected to a series of tests to ensure that the systems and components met the specifications. The company possessed a well developed testing laboratory.

The quality manager suggested that, while quality system set up the structure and process of quality management in the company, the 'human factors' played an important role in achieving the effectiveness of the quality system. The positive attitudes of employees at all levels and the real commitment to quality from the top management were essential for implementing quality assurance. The quality procedures that defined in the quality system described what should be done. However, it was those who were actually implementing the procedures to ensure that the procedures were followed. The quality manager audited the quality system regularly. Problems and nonconformance could be found during the quality audits. However, quality assurance was not about finding out nonconformance but about preventing the occurrence of nonconformance. The quality manager had to work across various departments in the company. support from colleagues as well as top management were essential for him to work effectively.

Appendix 16 Company Profile N

Company N was a specialised automatic sprinkler systems installer. It employed about thirty staff. About twenty of them work in office, while six of them work on site and four of them work in a small workshop.

The company gained the quality certificate to its quality system in November 1992, from the Loss Prevention Certification Board (LPCB). The quality system was complying to BS5750 Part 1.

The company started planning for quality assurance in early 1992. The company management perceived the pressure from both the clients and the LPCB, and decided that the possession of a certified BS5750 Quality System would be necessary for the company to develop its business.

At the early stage of the quality assurance programme, quality management consultant was employed to help the company to set up the quality system. The consultant made investigation into the business operation procedures in the company and worked out the documentation of the quality system. However, some problems rose when the quality system was actually put into practice. Many quality procedures that were defined in the quality system appeared to be unacceptable because they were, in the word of the engineering manager, 'too different from what we were doing'. If these quality procedures were to be implemented in the company, many operational procedures that had been in practice in the company for years had to be changed.

For example, the quality system set up a series of file management procedures for the documentation of contracts and projects. According to these procedures, the existing files in the company might have to be rearranged, and the existing procedures might have to be changed radically. Nobody in the company liked that. Staff including managers complained that the quality procedures only produced extra work burden and made no sense to improve anything. Their old way of doing things were effective, and there was no reason to change it. Therefore, the first quality system that was developed by the quality consultant was abandoned.

Then the present Quality Manager was sent to a BS5750 training course. He produced a new quality system afterward, which was based on the existing business operation in the company. The new Quality System required litter change in the ordinary business operation, but introduced certain new operation procedures. This quality system was accepted by employees and management at all level of the company.

The company obtained contracts for various types of clients, including architects, general building contractors, management contractors, project managers, building services contractors and client representatives. This meant that the company was involved in building projects which were contracted under various forms of building procurement systems. However, the general operation procedures that the company used for contracting and managing projects were not influenced by the forms of the building procurement systems. The company had established a series of standard procedures as well as documentation throughout the project process which usually started from enquiry review and quotation and ended with commissioning and hand-over.

Appendix 17 Publications Produced During the Study

1. "Assuring the Quality of Fire Safety Systems in Buildings", in *Fire Prevention*, July/August 1993, pp27-31.

2. "Quality Assurance in Fire Safety Engineering Firms", in *Journal of Applied Fire Science*, Volume 3, Number 1, pp53-68.

3. "The Macro Quality Assurance System for Fire Safety Engineering", in *Fire Technology*, Volume 30, Number 3, pp366-373.

Assuring the quality of fire safety systems in buildings

Quality assurance assumes special importance when considering fire safety products and systems, as life and property may be at risk if they do not perform as required. Xuefeng Xiao, Eric Marchant and Alan Griffith discuss how to ensure the quality of a fire safety system in a building

Fire safety quality assurance in building construction has to be approached in a different way to product manufacture. Practically all building projects are unique - few have the same design or similar location. By the same token, every fire safety system is a unique combination of sub-systems and components with different performance requirements and quality charateristics
Photo: Timothy Soar

THE QUALITY of products and services has become a fundamental influence on business development and survival in the present highly competitive market. Quality assurance schemes are now being introduced into more and more sectors of industry throughout the UK.

In the fire protection field, product quality tends to be more important than in other industries, as the equipment produced is directly linked to the safety of life and property.

One feature of the recently revised Building Regulations[1] is the acceptance of the fire safety engineering approach to the design of buildings. This approach can offer many advantages, but it is important to ensure that adequate levels of fire safety are maintained throughout the life of a building. It is also important that all the facilities and equipment installed as part of the fire safety system meet the necessary requirements.

This article discusses how to ensure the quality of the fire safety system in a building - and how to maintain that quality.

What is fire safety engineering?

A general definition of fire safety engineering is 'the application of engineering concepts and techniques for achieving fire safety in a building or any other structure'[2]. Fire safety engineering is an integration of expertise and techniques from an wide range of scientific and engineering disciplines. It aims to provide a building with technical measures that have been designed and engineered to provide and maintain an adequate level of fire safety. This objective has three major aspects:

- Protection of life
- Protection of the building and its contents
- Prevention of conflagration

When adopting a fire safety engineering approach, it is important to consider all the fire safety measures involved in an integrated package.

One of the problems in current practice is that separate parties are responsible for providing different sections of the fire safety system[3], although a more systematic approach is developing.

Nevertheless, the outcome of a fire safety engineering approach can still be seen as a system which integrates all the necessary technical measures to achieve the necessary level of fire safety.

This integrated package can be defined as a 'fire safety assurance system'. The objectives of this system can be specified as follows:[2,4]

- Control of ignition
- Detection of fire
- Control of fire growth and spread
- Provision for escape
- Control of smoke movement
- Protection of building structure
- Provision of fire-fighting facilities and access
- Fire safety management

What is a fire safety system?

A fire safety assurance system can be described as a combination of two parts (see Figure 1):

- **A 'hardware' sub-system** - all the fire protection equipment and facilities.
- **A 'software' sub-system** - managerial measures concerned with fire safety, such as training of staff, operation and maintenance of equipment, and emergency plans.

The 'hardware' sub-system can be referred to as a 'fire safety system'. It is this system with which this article is concerned.

The basic structure can be described as an open system with distinct but interdependent sub-systems. The structure may vary from building to building and some of the sub-systems shown in Figure 1 may not be required in a simple building. But it is not difficult to see that this system exists in most modern buildings.

What is quality?

The word 'quality' is used frequently today in the business world, as well as in daily life. The perception of quality of an item or service is something both subjective and objective. It is often linked with the sense of 'excellence', 'fineness', 'value-for-money', as well as terms such as 'function', 'reliability', and 'durability'. But to make quality 'manageable', it is necessary to define it as objectively as possible. There are several definitions of the term 'quality' commonly used by professionals:

❑ Fitness for purpose.[5]

❑ Conforms to requirements or specifications.[6]

❑ 'Total quality' - the composite characteristics of engineering, manufacture, marketing and maintenance through which the product or service will meet the expectations of the customer.[7]

Generally, quality is meeting the requirements - to quote Oakland[8]. But it does not always mean the same thing for different products or activities. The perception of the quality of a luxury car is rather different from that of a truck, because users expect them to fulfil very different purposes.

It is important to have a clear understanding of the true meaning of quality when a specified product or a particular activity is involved.

What does quality really mean for a fire safety system? Before answering this question, consider the following:

◆ Every fire safety system is a 'unique' product. Requirements vary from one building to another and the structure and performance of fire safety systems change accordingly. Few systems are ever repeated exactly.

◆ The quality of a fire safety system has a special social meaning. Its purpose is to provide protection of life and property. Failure of a fire safety system in the event of a fire could cost a great deal more than the value of the system itself. It may result in severe damage to the building and its contents, and could cost human life.

◆ The performance requirements of fire safety systems are regulated in part by the statutory authorities. In many cases, specification of fire safety systems is mandatory - although the clients usually have their own choice of the system designers, installers and component suppliers. In some cases, clients may feel they are being asked to spend too much money.

◆ Quality of fire safety systems is the concern of customers and suppliers, as it is usually the case with ordinary consumer products. But parties who are not part of the purchase/supply chain - for example, building control authorities, fire authorities and insurers - also have an important say.

Figure 1. The structure of a fire safety assurance system

These features largely influence how the requirements of a fire safety system are defined and how the quality of the fire safety system is assessed.

Dimensions of quality

Quality may well be 'meeting the requirements', but the quality of fire safety systems can be measured by the following six dimensions:

❑ Performance

Performance refers to the functioning characteristics of a product or system. It reflects the basic purpose of the product or system. It can be defined clearly in specifications.

Performance is a familiar term in fire safety engineering. The traditional fire tests are mainly concerned with the performance of products and materials. Performance of a fire safety system is defined by the total fire safety requirements of the building. While performance of each fire safety sub-system is measured against its functional specification, performance of the whole system is measured indirectly by the totality of the performance of the sub-systems.

As mentioned previously, the sub-systems and components of a fire safety system are designed and installed separately by different professionals because of industry tradition. Lack of co-ordination between these participating parties could result in an uncoordinated total system - which may not function as expected.

It is therefore important to have a clear specification in the early design stage which defines all the functioning requirements of the system. It is also important to co-ordinate the whole process of procurement, from design to commissioning and completion.

Performance is the basic measurement of quality, but high performance does not always mean better quality. For example, a door with a high fire resistance may be of poor quality if it is easily broken in daily use, or its appearance is detrimental in the environment where it is used.

❑ Reliability

Reliability reflects the probability that a product or system will not fail to perform consistently over an expected period of time. Reliability of a fire safety system is not only as important as that of any other engineering system, but it has a special meaning.

For example, the failure of a fire detection system during testing would cost little but if it failed in a fire, it could cost lives. The type of failure can also be important - if a fire alarm system failed to give an alarm in the event of a fire, it could be far more harmful than a false alarm.

Some fire safety systems may never have a chance to perform their functions simply because a fire does not occurs, so their failure may never be known. For example, a fire door could have a reduced fire resistance for some reason, but the defect could remain hidden as the door may never be exposed to a fire.

❑ Durability

Durability is a measure of the life span of a product or system. Theoretically, the life span of a fire safety system should be the same as that of the building. But some components will inevitably need regular maintenance and other parts may need to be replaced over time.

Some components or sub-systems - such as fire doors, structural fire protection and smoke control or ventilation equipment - may have multiple functions and be in daily use. The durability of the fire safety functions should be distinguished from their other functions.

It is hard to believe that a fire-resistant building component would perform to the same standard after 20 years use as when it had just been installed. However, some fire tests do consider durability[9].

❑ Ease of maintenance

Given that some components will need maintenance or will have to replaced, it is important that a fire safety system can be easily maintained. This will help ensure that the life span of the system matches that of the building.

Some products are easy to maintain, while others clearly are not. A high-quality system will be one that is easy to maintain. Also, maintenance services must be readily available so any problem can be fixed quickly.

❑ Economy

Although it is easy to understand that a good fire safety system should be economic, it is difficult to define what is a cost-effective system. Many existing fire safety systems are unlikely to be cost-effective, with some buildings possibly being 'over-protected'.

Research carried out in by the Warren Centre in Australia[8] suggests that a saving of some $200 million per year could be achieved without reducing the current level of safety in high-rise and other buildings. The study also suggests that the traditional approaches to the design of fire safety systems are unlikely to lead to the most cost-effective outcome.

❑ Aesthetics

Aesthetic considerations are less important than functional characteristics - a lack of aesthetics will not influence the performance of a fire safety system. But aesthetics reflects a degree of excellence and may affect the building's overall fitness for use.

Although this a subjective area, basically the appearance of the system should be pleasing and the components should fit in with the rest of the building. The degree of pleasure and harmonization will be judged by the viewer's own preferences. But system designers - as well as the component producers - should consider the aesthetic aspects of their products.

Assuring quality

A fire safety system is a part of a building. Its sub-systems and components are interrelated with many other parts of the building. For example, an emergency lighting system is closely linked to the illumination and electricity supply systems, and a sprinkler system will be connected to a water supply system.

Figure 2. Procurement process for a fire safety system

While these systems and the like are mainly the concern of fire safety specialists and building services engineers, passive fire protection, fire compartmentation and smoke control are the concerns of architects, structural engineers and building services engineers.

Because of the complex nature of a fire safety system, its procurement is divided into several parts and undertaken separately by different specialists. Traditional building technology also limits the possibility of managing the design and installation of all fire safety sub-systems within one integrated package.

These problems require that the fire safety engineering approach considers the performance and quality of not only individual sub-systems, but also the performance of the system as a whole.

Quality assurance procedures must ensure the co-ordination of all the fire safety sub-systems. The total performance of the system must be assured to maintain the expected level of fire safety in the building.

One factor affecting quality assurance in construction is that practically all building projects are unique[10]. Unlike product manufacture - which is usually undertaken on a mass-production basis - a building is usually a one-off, essentially a prototype.

Few buildings have the same design, or similar location or environmental conditions on the construction site. By the same token, every fire safety system is a unique combination of sub-systems and components with different performance requirements and quality characteristics.

Quality plans should be set for each fire safety system to define and specify quality standards in accordance with the requirements of the building in which the system is to be installed.

The methods of contracting and managing the building project also vary from project to project. Franks[11] summarizes seven major building project management systems: the traditional system, construction management for a fee, package deal and turnkey systems, design-and-build, separate contracts, project management and the British Property Federation system.

As a part of the building project, fire safety sub-systems and components are procured through various forms of contracting. Designers and installers of various fire safety sub-systems are brought into the building project team at different stages.

An overall quality plan is needed to ensure the communication and co-ordination between all participants. Each sub-system also needs a detailed quality plan to guide the quality assurance activities.

The conceptual design of a fire safety system should be a part of the conceptual design of the building, and the system should develop as building design and construction develops.

The complexity of the procurement system makes it almost impossible to set up a detailed quality plan to cover all the necessary activities for quality assurance. Therefore, the quality plan(s) for a fire safety system must be developed and reviewed over time. The general procurement process can be described as in Figure 2.

After the building brief has defined the performance requirements for the total fire safety system, the concept design is undertaken by the architect or the consultant fire engineer. Specialist fire engineering contractors then design, install and commission the sub-systems.

While some effort is made to co-ordinate the sub-system contractors throughout this process, the commissioning of the total fire safety system, which brings together all the sub-systems, is conducted at the end of the whole building project.

A set of quality plans - along with the building project plan - is needed to define the basic requirements of quality assurance, and how the quality assurance of the whole system - as well as of each sub-system - is to be achieved.

A systematic approach

A systematic approach to quality assurance is shown in Figure 3.

This is based on staged quality plans, supported by quality management systems in the contracted companies. The quality planning is divided into two major stages.

◆ Stage 1. The first stage is to set up an overall quality plan for the whole fire safety system, ie the total system quality plan.

◆ Stage 2. The second stage is to develop a set of 'sub-plans' for every fire safety sub-system, ie the sub-system quality plans.

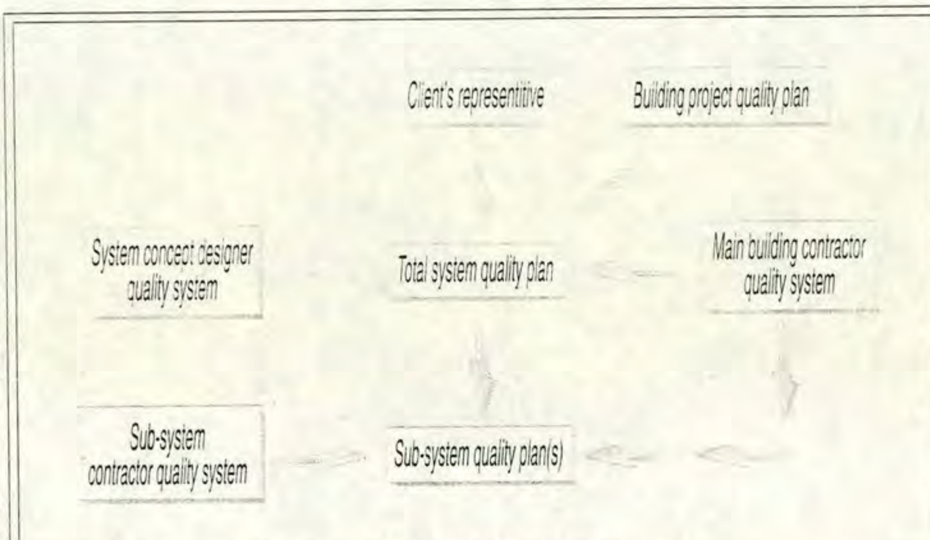

Figure 3. Framework of a systematic approach to quality assurance

Division of these two stages over time will vary according to how the building project management is arranged.

All the quality plans should be reviewed and revised at appropriate stages of the project. The companies who are contracted to the project - the system concept designer, the main building contractor, the sub-system contractors, and possibly the client's representative - are expected to operate a quality management system in their own organizations.

❑ Client's representative

The client's representative is the person or organization who is appointed by, or contracted to, the client to manage the building project or particularly the fire safety system project.

Perhaps an employee of the client, the architects or their agent, or an employee of the management contractor, this representative should be the person who takes the responsibility of organizing and overlooking the quality assurance activities for the whole project.

It is unlikely to be practical for such a person to actually draw up the whole quality plan. Neither is it practicable for them to take full responsibility for quality of the work done by a sub-system contractor. But it is their responsibility to organize the development of the total system quality plan and monitor its implementation.

The representative must ensure that the quality plan has been developed in a proper way by a qualified person or consulting organization and that it is implemented properly. If necessary, a quality manager should be appointed to help the client's representative.

In practice, the quality plan for the fire safety system will usually be a part of the whole building project's quality plan. The fire safety system quality manager can then be the quality manager for the whole building project.

But the quality manager should not be the only person who takes responsibility for quality. It is the client's representative who should be responsible directly to the client for all issues related to the quality plan.

❑ Total system quality plan

This is the overall quality plan for the total fire safety system project. It should be made before or at the beginning of the concept design stage shown in Figure 2.

The plan should set up a framework of quality assurance for the whole fire safety system and the quality procedures for concept design stage in particular. It should be reviewed and modified as the project develops.

A typical total system quality plan should include the following:

◆ The total quality objective to be attained. The total performance requirement for the system should be specified and requirements for other quality parameters should also be clearly defined.

◆ Quality assurance requirements for the concept design contractor.

◆ Specific allocation of quality responsibility and authority during the concept design stage.

◆ Specific quality procedures and methods to be applied in concept design.

◆ Specific procedures and methods for communication between concept designer and other parties such as the architect, sub-systems designers and installers, the structural engineer, building services engineers and other specialists.

◆ Quality assurance requirements for contractors involved in the design and installation of the fire safety sub-systems.

◆ When and how the sub-system quality plans are to be developed.

◆ Methods and timetables for auditing the total system quality plan.

◆ Methods and appropriate time schedules for review and modifications of the total system quality plan.

◆ Other necessary measures.

When the concept design phase has been completed and contractors of fire safety sub-systems have been appointed, it is necessary to revise the total system quality plan.

The emphasis of the plan in the next stage is to control and co-ordinate the interface between different sub-systems, as well as between different sub-contractors. The detailed procedures for interface control should be set according to the structure of the total fire safety system and the contractual arrangement of the design and installation of the sub-systems.

❑ System concept designer

The system concept designer is the person or organization that designs the overall concept of the fire safety system. Usually they will be either the architect or a consulting fire engineer. They may contract directly to the client or to the client's representative, or may be the client's representative themselves. Whatever the contract arrangement is, they should take full responsibility for the quality of the design. The designer's responsibility and authority must be clearly specified in both the contract document and the quality plan.

❑ **Main building contractor**

The main building contractor is the company which undertakes the major project construction work. Most fire safety sub-systems are designed and installed by specialist contractors.

The relationship between the main building contractor and the sub-system contractors varies from project to project. The sub-system contractors may be sub-contracted to the main building contractor, or contracted directly to the client.

However, the quality of the fire safety system largely depends on the co-operation between the main building contractor and the fire safety sub-system contractors. It is essential to define in the quality plans the responsibilities of both parties and the method of communication between them.

❑ **Sub-system quality plans**

These are the quality plans for individual fire safety sub-systems. The concept design specifies the structure of the fire safety system, ie the number of fire safety sub-systems to be used in the building.

Each fire safety sub-system should have a detailed quality plan. It is important to note that these plans should be made on a project basis rather than a sub-contractor basis, especially when the design and installation of the sub-system involves more than one company and consultant engineer.

A sub-system quality plan should typically include:

◆ Specification of the quality requirements for the fire safety sub-system.

◆ Allocation of responsibilities and authorities during different phases of the sub-system design, installation and commissioning.

◆ Specific procedures, methods and work instructions to be applied. If there is more than one contractor, specific measures should be defined to ensure a good interface.

◆ Measures to ensure communication and co-ordination between the sub-system contractor and the main building contractor, other sub-system contractors, and other parties in the project team.

◆ A schedule for inspection, testing and quality auditing.

◆ Methods and timetable for review and modification of the quality plan.

◆ Other necessary measures.

❑ **Sub-systems contractors**

These are the companies or people who contract to design and/or install a specific fire safety sub-system. Some typical sub-system contractors are sprinkler installers, fire detection system designers and installers, and fire and smoke door installers.

Sub-system contractors play a very important role in the quality assurance of fire safety systems, for most of the project work will be completed by them. With the development of quality assurance and certification schemes, it is expected that every sub-system contractor has a quality management system in its company. The sound quality management practice in contractor organizations provides the essential basis for the quality assurance of the fire safety systems.

The human touch

Beyond all the quality plans and quality assurance systems, an important issue which has not been discussed is the 'human aspect' of the quality assurance.

A series of interviews conducted by the principal researcher in a number of fire safety engineering firms, showed that systematic quality management in most companies is only just beginning to be widened. Quality awareness, motivation, and corporate culture are long-term targets to be achieved after the companies have obtained their quality assurance system certificates.

Although the operational quality assurance measures are important to the achievement of quality, they can only be as effective as they are expected to be when the operators are fully aware of their importance and are highly motivated to follow the specified procedures.

The organizational complexity of the fire safety system project requires greater emphasis on the human aspect of quality assurance. Quality of fire safety systems, like that of any system, will be achieved by the collective efforts of all project team members within a quality culture.

Following the wide application of quality assurance systems in fire engineering companies as well as in other companies within the construction industry, intensive research should be conducted to investigate the effectiveness of quality assurance on the improvement of quality and the creation of quality culture ❑

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QUALITY ASSURANCE IN FIRE SAFETY ENGINEERING FIRMS

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ABSTRACT

The practice of quality management is widespread in industry in the United Kingdom (UK) but little was known about the impact of quality management in the fire related industries. Information has been gathered through a series of personal interviews and through a questionnaire survey of eighty-eight firms. The principal reasons for modifying the work patterns of the firms to accord with the rigor of quality management included: a demand from a client company; the fact that competing companies with quality certification may win a permanent market advantage over those companies without such certification; and the management of some companies considered that certification was good for the development of the business. After certification there is likely to be an improvement in the management structure of a company but this may not be maintained if the creation of a quality-oriented corporate culture is not attained.

INTRODUCTION

Quality assurance as a quality management tool has been widely adopted by companies in the fire protection industry during recent years as it has been in many other industries within the United Kingdom. The fire protection industry is a very complicated industrial area, which involves many engineering disciplines. Some special features of the fire protection industry are affecting the development and implementation of quality assurance in many ways, both positively and negatively. Recently, the authors have made an attempt to examine the causes and effects of quality assurance in fire safety engineering firms and to identify the key factors which affect the effective application of the quality assurance system in these firms.

To some extent it is difficult to investigate in great detail the technological issues of the application of quality assurance in all sectors of the fire protection industry because of the great diversity of the fire safety engineering firms and the complex structure of the industry itself. However, it is helpful to examine some general features of quality assurance in regard to the whole industry and to make some comparative studies between different types of fire safety engineering firms. With this purpose, a series of interviews and a questionnaire survey have been conducted in a number of fire safety engineering firms who have introduced quality systems and have obtained quality assurance certificates. This article discusses the findings of this investigation.

In the survey, questionnaires were sent to eighty-eight companies and fifty-six valid responses were obtained. Statistical methods have been used in the data analysis where it was appropriate. However, because of the relatively small sample size and large diversity of some variables, much of the analysis is based on descriptive methods to reveal the trends inherent in the responses.

First, an examination is made on some general features of fire safety engineering firms which would have effects on the application of quality assurance in those firms. This is followed by a discussion of special factors which influence the effectiveness of the QA systems. In the last part of the article a comparative study of manufacturing and installation firms is made to ascertain the differences between these two types of companies.

DIVERSITY IN FIRE SAFETY ENGINEERING FIRMS

Although the fire protection industry is only a small and emerging industrial sector within the construction industry, its industry structure is rather complicated because of the complex nature of fire safety engineering and industrial traditions. This complexity is reflected in the great diversity of fire safety engineering firms. The diversity of these firms is characterized in the following three summaries.

1. Large Firms and Small Firms

Fire safety engineering firms vary greatly in their size. Of the fifty-six companies surveyed, eleven companies have numbers of employees below thirty and annual turnover less than £2m, while two companies have employed more than 100 people with annual turnover of more than £50m. Table 1 (a) and (b) show the distribution of numbers of employees and the annual turnover of the fifty-six companies. Although this distribution is not likely to represent the actual proportion of company sizes of all the fire safety engineering firms, it reveals the fact that the diversity does exist. Research shows that business strategy and management techniques to be employed by a company can be influenced largely by the size of

Table 1. Size Distribution of the Surveyed Companies

(a) Number of Employees

Number of Employees	Number of Firms
Under 10	3
10~29	10
30~49	10
50~99	12
100+	21
Total	56

(b) Turnover (in 1992)

Under £1m	2
£1~2m	12
£2~5m	14
£5~10m	5
£10~50m	17
£50m+	2
Missing	4
Total	56

the company. "Small firms" have been recognized as a specified category of businesses which need special concern over their development and management [1, 2].

It is revealed from the survey that, when compared with the small firms, larger companies are likely to have a more positive attitude toward quality assurance and obtain more benefits from it. It is also suggested that the average pre-experience (the previous experience in quality management before the company started quality assurance), among large companies is more than that of small companies.

2. Discrete Business Areas

Fire safety engineering is a composite application of knowledge and expertise from various engineering disciplines. Because of the very nature of fire safety engineering, and also partly because of industrial traditions, fire safety engineering firms are grouped under a range of specialized business areas such as fire extinguishing equipment and systems, fire detection and alarm equipment and systems, smoke control facilities, fire resistant building components, and other products and services. Many of these industrial groups are in fact distinctive industry sub-sectors with their own specialized industrial organizations and trade associations. Only a small number of large firms are involved in several business areas within the several parts of fire safety engineering.

Each of these industry sectors has its own client base and market environment, its specific product and service requirement, and different business practice codes and customs. As quality assurance is introduced to each of these industry sectors, it is influenced by their different characteristics.

3. Manufacturing versus Installation and Service

Fire safety engineering firms can be grouped into the manufacturing sector or the service sector. Fire safety engineering firms in the manufacturing sector are involved in the fabrication of fire protection equipment and its components. Fire safety engineering firms in the service sector, which belong in the construction industry, undertake design, installation, and maintenance of fire safety engineering systems. Beyond these two groups, there are only a small number of large firms which are involved in both design, installation, and the manufacture of the fire safety systems. The difference between the nature of manufacturing and that of construction requires that when the quality assurance mechanism is transformed from manufacturing to construction, careful modifications are needed [3-5]. The survey results reveal different experiences of manufacturers and installers of fire safety systems on their quality assurance activities. A detailed discussion on this issue is made in the last part of the article.

QUALITY ASSURANCE PROGRAMS AND SOME GENERAL INFORMATION

One of the purposes of the survey is to investigate some general aspects of the "Quality Assurance Programs" of fire safety engineering firms, such as "How many months or years did it take the companies to prepare their quality assurance systems?" "What experience had they had in quality management before the quality systems were introduced?" "Whether or not did they feel pressure from outside their organizations at the time they decided to introduce quality systems?"

A quality assurance program, whether it is named as such or not, is usually launched when the company has decided to introduce the quality assurance system into its organization. The program is usually implemented in two stages: 1) the preparation stage and 2) implementation stage, although these stages may not be distinguished by the management of the companies.

1. The preparation stage commences when the decision is made that the company is to install a quality assurance system, and is completed when a quality certificate is obtained. It involves establishing the quality system, training staff,

the initial operation of the system, registering with a certification scheme, and other related matters.

2. The implementation stage commences after the company has received the quality certificate. In this stage the quality system is put into formal operation under regular surveillance of the certification organization; new quality procedures are customized; and any changes caused by the new system are internalized. The length of this stage depends on many organizational characteristics of the company. The company may consolidate the quality assurance program with other quality improvement programs and progress to a higher level of quality management.

The survey shows that, of the valid forty-four responding firms, 50 percent of them spent less than one year on preparation stage, while another 43.2 percent spent more than one but less than two years. Among all the fifty-six surveyed firms, twenty-four (42.8%) of them have achieved quality system certificates for less than two years, while nineteen (33.9%) firms have held their certificates for more than three years.

Other information revealed by the survey includes the following:

1. Among the fifty-six surveyed companies, only twenty-six companies had some quality procedures similar to the requirements of The British Standards Institution (BS5750) before they formally adopted the quality systems. The remaining thirty firms had no previous quality procedures of this kind.
2. Forty-two companies claimed that they felt pressure from outside the company demanding quality assurance. Of the organizations and groups which created this pressure, certification bodies and clients are the most persuasive ones, while business rivals have also had considerable impact. Detailed discussions follow in the next section.
3. Twenty-four of the fifty-six companies are registered with more than one certification body. Most of the companies are registered with the Loss Prevention Certification Board (LPCB) and the Quality Assurance Services of the British Standards Institution (BSI/QAS).

REASONS FOR ADOPTING QUALITY ASSURANCE

The reasons for fire safety engineering firms introducing quality assurance into their companies are investigated in the research. The major motivators which cause a company to start its quality assurance program are identified as: 1) client's need; 2) market competition; 3) development of certification schemes; and 4) the company's business development strategy.

Client's Need

The demand from clients is the most important driving force for quality assurance. Quality is about meeting the customer's or client's requirement. The highly competitive market provides clients with a wide range of options. Quality has become an important factor that influences client's choices of the products or services they need. Quality assurance is regarded by clients as evidence of the supplier's achievement of quality management and, therefore, gives them confidence to procure from that supplier. Fire safety engineering firms are increasingly under pressure from their clients who demand quality assurance. In the survey, thirty-one out of the fifty-six companies claimed that they frequently received enquiries from clients in regard to their company's quality assurance status and quality management practice.

Market Competition

Market competition is another important motivator of quality assurance. The effect that market competition has on quality assurance results from two facts; that clients are always demanding, or rather, preferring better quality; and that business rivals are improving their performance in quality management. While the client's preference of better quality products or services provides the base for competition, the conduct and performance of business rivals set the competition rules. When business rivals have advertised their achievement of quality assurance, the company would almost certainly feel that it would lose to competition if it failed to attain the same quality certificate. The survey shows that a considerable number of fire safety engineering firms felt pressure not only from their clients but also from their business rivals.

Certification Schemes

A notable finding of the survey is that the certification body plays an important role in the promotion of quality assurance within the fire protection industry. The survey result shows that certification bodies have produced a significant pressure for quality assurance on the fire safety engineering firms involved in the survey.

Certification bodies are the medium through which quality assurance is accomplished. The quality certificate issued for a product or a service under a certification scheme is regarded by customers and clients as evidence of quality. A certification scheme interprets customer's requirements into its technical criteria on which the suppliers' quality systems as well as their products or services are assessed. Based on the recognition from both customers and suppliers, certification bodies acquire the power for promoting quality assurance by establishing new certification schemes and revising the criteria in current schemes. Any change in a certification scheme can cause substantial effects in quality assurance practice within the industrial area it covers. In such a recent event, the Loss Prevention Council, an authoritative certification body in the fire protection industry, replaced its traditional quality approval schemes with its new quality certification schemes under which the quality system is a compulsory requirement. This new policy has had a great impact on promoting quality assurance in fire safety engineering firms. In a series of interviews supplemental to the questionnaire survey, a number of quality managers suggested that their companies would not have developed their quality systems had it not been required by the LPCB's new certification scheme.

Apart from certification bodies, clients, and business rivals, other organizations also have some influence on the development of quality assurance in fire safety engineering firms. Table 2 presents a summary of these organizations.

Business Development Strategy

External pressure is, undoubtedly, the important driving force for quality assurance. However, it is not the only driving force. While forty-two of the fifty-six surveyed companies felt pressure from outside their organizations at the time they developed their quality systems, the other twelve companies claimed that they did not feel any such pressure. The major reason for them introducing quality assurance systems was their awareness of the need for quality assurance among their potential clients in the future market. Seeking future business development and attaining leadership in the future market, these companies adopted a strategic approach to introduce their quality assurance systems. Not only to secure the existing market by satisfying current demand but also to meet the future demands of quality assurance as a vehicle to pursue long-term profit.

Table 2. Responses to Organizations from Which the Companies Felt Pressure

	Count	Pct of Cases
Certification body	29	69.0
Clients	24	57.1
Business rivals	14	33.3
Government	10	23.8
Fire authorities	10	23.8
Insurers	9	21.4
Trade associations	9	21.4
Building authorities	7	16.7
Fire professional institutes	4	9.5
Valid cases	42	

BENEFITS AND DRAWBACKS OF QUALITY ASSURANCE

Results from the survey reveal that application of quality assurance has benefited the fire protection industry in general. The main benefits of the quality system which have been experienced by the companies involved in the survey are summarized as following list:

- formalizing working procedures,
- improving traceability of work,
- improving communication,
- improving organization efficiency,
- improving quality,
- improving marketing competitiveness, and
- reducing error and mistakes.

The survey results also indicate that some companies have gained more advantages than others. A few companies claimed that they have not seen any of the benefits listed above. Among these benefits "formalizing working procedures" and "improving traceability" are the most popular.

A major drawback to quality assurance which has been experienced by a majority of the companies is that it increases work burdens. An increasing financial burden is regarded as another major drawback by many companies.

Nearly 80 percent of companies believe that quality assurance is cost-effective or will be so in a long term. The remaining 20 percent of companies either think that quality assurance is not cost-effective at all or state that they are not sure about it at the moment.

SOME FACTORS WHICH AFFECT THE EFFECTIVENESS OF QA

Quality assurance is an effective tool to improve quality and organizational efficiency. However, it is not a guarantee for success. A quality system sets up the necessary organizational structure and working procedures within a company to ensure that products and services are conforming to client's requirement. However, the effectiveness of quality systems is largely affected by various factors that stem from the business environment of the company and the behavior of its members. The successful and unsuccessful experience of some companies suggest that quality assurance requires a company not only to establish a quality system but also to accomplish a series of organizational changes that are necessary for the achievement of a commitment to quality. Some factors that affect the accomplishment of the changes and their effects on implementation of quality systems are discussed below.

The Gap Between Different Goals

Quality assurance, as Juran defines it, "is to provide the evidence needed to establish confidence that the quality function is being performed adequately" [6]. In current practice, quality assurance is built on the mechanism of "third party certification." A quality certificate issued by a third party, a certification body, to the supplier is regarded by clients as the evidence upon which confidence on the quality of products and services are established. A company starts its quality assurance program for various reasons such as to meet a client's requirement, to compete with business rivals, to improve the image of the company, or to improve quality of its products and services. The immediate goal of a quality assurance program, however, is always to gain its client's confidence and therefore to advance its market.

Behind such an immediate goal of obtaining a quality certificate, the purpose of quality assurance is to ensure that all products and services supplied by the company are consistently meeting quality requirement. It is the output of consistent quality that is the final goal of a quality assurance program. To achieve constant quality, the company should not only develop a capability to deliver quality products and service, but also achieve a full quality commitment from all members of the company. A certificate to the quality system in accordance with the requirement of BS5750 confirms the possession of such a capability. But it hardly proves that the company has achieved a real commitment.

The research results suggest that the acquisition of a quality certification does not always result in the achievement of such a commitment. In some interviews managers revealed their negative views on their quality systems. They felt that they were forced to have a certified quality system by external pressure such as the certification body (LPCB) and some clients. A quality certificate is important for their companies to develop business. Without such a quality certificate their companies would lose their market shares. However, they see no need for the quality system itself. They do not believe that the quality system will improve either their work or quality. Although such companies possess a quality certificate, they are not likely to have achieved a commitment to the implementation of their quality systems. Nor are they likely to have achieved a full commitment to quality. There remains a gap between the achievement of quality certification and the achievement of quality commitment.

Quality commitment is essential for the effectiveness of a quality system. It is related to quality awareness, motivation, and attitude of members of the company. A corporate culture that stresses the value of quality provides necessary environment for the achievement of individual's commitment to quality.

Pre-experience

"Pre-experience" refers to the previous experience that a company has in formal quality management before the quality system is established.

It was revealed from the survey that pre-experience had a meaningful effect on the company's attitude to quality assurance and the benefits they have experienced. Companies with pre-experience tend to have a more positive attitude toward the beneficial effects of quality assurance and see quality systems as more cost-effective than those companies without pre-experience.

Apart from the organizational structure aspect of the quality management which is greatly emphasized in the quality system, the human behavior aspect of the quality management, which includes awareness, attitude, and commitment, is equally important to quality assurance. Introduction of quality assurance brings changes to various aspects of a company. Less pre-experience usually means that greater changes are required, both to the organizational structure and to the aspects of human behavior. Organizational change, especially change in human behavior, is a long term process which needs consistent effort. To companies who have little pre-experience it is essential to promote quality awareness within the whole organization and to create a quality-oriented corporate culture.

External Pressure

External pressure that come from clients, markets, certification schemes, and other sources demanding quality assurance is an important driving force for the development of quality assurance. It is also an influential factor that affects the effectiveness of the quality system.

The survey result shows that companies that began their quality assurance programs merely to meet external pressure tend to have some negative attitudes toward quality assurance. On the other hand, companies that developed their quality systems without external pressure, appear to be more positive in their attitude to the effectiveness of quality systems. Among the fourteen companies who claimed that they did not feel pressure from outside at the time when they started quality assurance, eleven of them indicated that quality assurance systems have been cost-effective in their companies while the other three companies believed that they will be cost-effective in the long term. Companies who indicated that quality systems are not cost-effective all fall into the category of those who developed their quality systems under external pressure.

According to Lippitt et al., organizational change occurs when a new driving-force for change has intruded into the field of change forces and the balance of driving-forces for change and restraining forces against change is broken [7]. External pressure for quality assurance is such a new driving force for change. However, no one likes to change. When people want to change, it is because they see the new behavior as being their own self-interest. When change is imposed and the members of the organization cannot see how the change benefits them, they may appear to change in order to test it or show loyalty, but such change is not likely to survive for long [8]. In some companies the introduction of quality assurance is demanded by external pressure, but members including managers of the companies see neither the need of quality nor the benefits of quality assurance. Although the quality system and new quality procedures are established and implemented, they may not be internalized. The goal and motivation of quality assurance in such companies may remain as the possession of a quality certificate. Quality commitment may not be achieved.

Resistance to Change

Quality assurance brings about organizational change. However, organizations are social structures intended to make behavior more predictable and efficient by rationalizing and depersonalizing it in the form of a bureaucracy. They are not meant to change [8]. A range of reasons which lead to the resistance to changes in the organizations are summarized by writers in organizational behavior and organizational change [9, 10]. As evidenced from the research, the resistance to changes initiated by the introduction of quality assurance mainly result from the following.

Lack of Awareness of the Need for Change

The needs for quality assurance have not been truly understood. Members in the company including some top managers may feel that their present system and working procedures are good enough and that the introduction of the new quality assurance procedures will not improve their work but increase work burdens.

Misunderstanding the Lack of Trust

Employees, even top managers of the company, may misunderstand the purpose of quality assurance, or do not really believe that quality assurance brings improved work performance and better quality. Some managers believe that quality assurance is only a tool for marketing and therefore the purpose of quality assurance becomes obtaining and maintaining the quality certificate. Quality procedures and work instructions may not be fully understood and trusted. On several occasions a few quality managers also showed their disagreement with the certification body over some certification criteria and argued that the certification body's requirements are only to put unnecessary work burdens on them.

Sunk Cost

The term "sunk cost" is used by organizational behaviorists to explain resistance to change caused by people's fear of losing their investments in the status quo [11, 12]. People may consider time and energy that he has spent on learning and mastering a set of operation to be investments. Any loss or reduction in their value may be felt as keenly as if actual money or property were involved. Resistance may be aroused if operations and skills already mastered are threatened to be written off as a result of change. When new quality assurance procedures and work instructions are introduced to alter some old work routes, quality managers can hear this kind of words from some senior personnel: "What is wrong with our previous ones?" "I've been working in this way for years. It never goes wrong. Why bother to change it?" "I've been working on this job for more than twenty years. Now you are telling me how to do it better?!"

Fear of Losing Security

Employees fear that their mistakes will be seen if quality assurance procedures are implemented strictly, which may, in their eyes, lead to embarrassment, and threaten their job security and promotion prospects.

Fear of Losing Autonomy

Quality assurance often requires greater inspection and supervision. For example, in some design offices, quality systems introduce a procedure of "double checks" which require drawings to be checked and signed by a second person as well as the designer before they are issued. This would be considered by the designer as loss of his autonomy and increasing dependence to others.

SOME COMPARISONS BETWEEN MANUFACTURERS AND INSTALLERS

Earlier in this article it was mentioned that there are significant differences between manufacturers and installers in their quality assurance practices. For the purpose of comparison, ten sprinkler installers and nine manufacturing firms were selected from the surveyed companies. The comparison shows a number of interesting features of their experience in quality assurance practice.

1. Nine of the ten installers felt an external pressure for quality assurance. Four of these companies felt pressure from the certification body only, due to the revision of the certification scheme. In the manufacturers group, on the other hand, only five of them felt external pressure at the time when they started their quality assurance program, while the other four companies stated that they introduced the quality assurance system for improving the product quality and for improving their marketing competitiveness in the future.

2. Six manufacturers had some formal quality procedures, similar to the requirements of BS5750, in operation before the formal BS5750 quality systems were introduced. However, only one installer had such quality procedures in place at the time when the formal quality systems were developed in these companies.

3. While client's need and marketing competition are recognized as important reasons for the development of quality assurance, manufacturers and installers are facing different client and market environments. It is interesting to notice that the quality awareness of the clients of manufacturers are higher than that of the clients of installers. Of the nine manufacturers, eight are frequently receiving questionnaires from their clients inquiring about their quality assurance status and quality

Table 3. Comparisons of Responses Between Installers and Manufacturers[a]

	Installers	Manufacturers
(a) Responses to Benefits		
Communication	3	5
	37.5	62.5
	30.0	55.6
Work Procedures	7	9
	43.8	56.3
	70.0	100.0
Efficiency	3	6
	33.3	66.7
	30.0	66.7
Competitiveness	0	8
	.0	100.0
	.0	88.9
Traceability	5	7
	41.7	58.3
	50.0	77.8
Quality	1	8
	11.1	88.9
	10.0	88.9
Reduce Error	3	6
	33.3	66.7
	30.0	66.7
Others	1	0
	100.0	.0
	10.0	.0
Not Yet Seen	1	0
	100.0	.0
	10.0	.0
Total	10	9

19 valid cases; 0 missing cases

Table 3. (Cont'd.)

	Installers	Manufacturers
(b) Responses to Drawbacks		
Financial Burden	8 72.7 80.0	3 27.3 37.5
Work Burden	9 60.0 90.0	6 40.0 75.0
Bureaucracy	5 83.3 50.0	1 16.7 12.5
Not Yet Seen	0 .0 .0	2 100.0 25.0
Total	10	8
18 valid cases; 1 missing case		
(c) Responses to Cost-Effect		
Yes		7 100.0 77.8
No	3 100.0 30.0	
Long Term	5 83.3 50.0	1 16.7 11.1
Not Sure	2 66.7 20.0	1 33.3 11.1
Total	10	9
19 valid cases, 0 missing cases		

[a]First number in each cell represents the count of number of respondents; second number in each cell represents the percentage of respondents between two groups (installers and manufacturers); third number in each cell represents the percentage of respondents among the same group.

systems, while six of the ten installers only receive such questionnaires occasionally and one installer has not yet received any.

4. Manufacturers see more benefits and less drawbacks of quality assurance than the installers do. Table 3 (a), (b), and (c) are the comparisons of the responses between the two groups to the benefits and drawbacks they have experienced and the cost-effectiveness of their quality assurance activities. Table 3 shows a clear difference between them.

DISCUSSION AND CONCLUSIONS

The changing business environment demands formal quality assurance in the fire protection industry. However, fire safety engineering firms have their special features which affect the development and implementation of quality assurance in their organizations. The major pressure on the requirement for quality assurance comes from clients, markets, and certification schemes, while business development strategy of the firms is also an important internal driving force for the development of quality assurance. External pressure and previous experience in quality management, together with other factors bearing on a company's own features such as size and production activity, have significant effects on the company's attitude to, and the benefits it obtains from the quality system. It is also important to recognize the gap between different organizational goals relevant to quality assurance and convert the resistance to the necessary change.

Having identified the features of its organization and those of its business environment which affect the implementation of quality assurance, company executives should create appropriate policies and measures to ensure that the quality systems are implemented effectively. For those companies who have not seen many benefits from their quality assurance programs, it is essential for the top management to create and maintain a positive attitude and to achieve a real commitment to quality. The introduction of a quality system to a company is a process of planned organizational change. While the quality system and certification schemes are mainly focused on the structural aspects of the organizational change, it is the responsibility of company executives to manage and promote the human behavioral aspect of change which involves change of attitude, achievement of commitment, and creation of a quality-oriented corporate culture.

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VIEWPOINT

The Macro Quality Assurance System for Fire Safety Engineering

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Abstract

The comprehensive application of fire safety engineering in modern buildings makes the quality of fire safety equipment a very important aspect of the achievement of fire safety. With its direct relevance to the safety of human life and property, the quality of fire safety engineering in buildings is of concern not only to builders and their clients, but also to various social groups and organizations, ranging from government bodies and business organizations to the individual users of the buildings. Results of the recent research by the authors indicate that the government, insurers, quality certification bodies, building authorities, fire authorities, and trade and professional bodies significantly influence the development of quality assurance in the fire protection industry in the United Kingdom. In this article, the authors explore how these social groups and organizations play their roles in the development of a macro system for quality assurance in the fire protection industry in the U.K.

Background of the Research

Quality assurance is seen as an effective tool for improving the quality of the fire protection industry in the U.K. As a result, a number of quality assurance schemes have been introduced. Many companies have established quality systems in accordance with BS5750/ISO9000 and have registered with quality certification bodies.

In a recent survey, the authors attempted to examine the causes and effects of the adoption of quality assurance within the industry and to identify the factors that affect the effective implementation of the quality systems in fire safety engineering firms. Results of the research, some of which has been published,[1] show that most companies feel external pressure that demands higher quality, not only from clients, but also from social groups and organizations such as the government, insurers, certification bodies, fire authorities, building authorities, and trade and professional bodies. Such external pressure is an important factor that affects the development of quality assurance.

Since then, further investigations have examined the processes through which these social groups and organizations exercise their influence on the issue of quality assurance. These groups and organizations form the social environmental settings within which fire safety engineering firms operate their quality assurance programs.

Thus, a detailed study of such environmental settings provides a deeper understanding of the development and implementation of quality assurance in the fire protection industry.

Quality Is the Social Concern

The highly competitive market provides consumers with a wide choice of quality products, and consumers' experience with quality has increased their awareness of "value for money." Consumers are now becoming far more concerned with quality than they were before and are demanding higher levels of quality. Price is no longer the most prominent factor that influences purchasing decisions.

Having perceived the market demand for quality, manufacturers recognize that quality is becoming a dominant factor among those who determine gains and losses of market share. Better quality not only brings to the company a better chance for business development, but it has also become a matter of survival. Those who are not concerned with the quality of their product will soon be out of the market.

From the viewpoint of an industry or a nation, quality provides strong support in the fight to win a larger share of the international market. The Japanese experience, in particular, demonstrates that quality can make a significant contribution to the development of the national economy. The British government's white paper on standards, quality, and international competitiveness,[2] published by the Department of Trade and Industry in 1982, recognizes the importance of quality at the highest level in the United Kingdom. It clearly spelled out the message: Quality is the key to reestablishing Britain's position as a leader in world markets.

In the context of fire safety engineering, one can interpret the fact that quality is the concern of the society in at least three ways. First, every member of society is interested in fire safety, and it is of concern to all social groups and organizations. While fire safety equipment and systems are used comprehensively in modern buildings, the quality of such equipment and systems is as important as their designed functions. Second, all parts of society require the assured quality of fire protection products. When an ordinary consumer product fails to function, the scope of the resulting damage is likely to be limited to the supplier-purchaser circle. However, the failure of fire safety equipment during a fire may have serious social consequences. Finally, the traditional structure of the fire protection industry sets up a unique social framework, or a macro social system, within which the issue of quality is a primary concern. This framework defines some special roles, such as those played by insurance companies and fire authorities, that are not usually found in other industries.

Framework of the Macro System

The social concern about the quality of fire safety engineering results in the development of a macro quality assurance system that includes the government, insurers, certification bodies, the building authorities, the fire authorities, and trade and professional bodies. The following sections discuss how each of these components works within the macro system.

The Government

The government's primary fire safety concern is the protection of human life. Its basic role in quality assurance is as a regulator and a promoter.

The Fire Precautions Act 1971[3] grants the British government the power to designate premises for which fire certificates are compulsory. The Fire Precautions (Hotels and Boarding Houses) Order 1972[4] and the Fire Precautions (Factories, Offices, Shops and Railway Premises) Order 1989[5] specify the types of buildings in which compulsory fire certification may be applied. Fire certification allows the fire authorities to make sure that certain levels of fire safety have been maintained in these buildings.

The *Building Regulations* are among the most important pieces of delegated legislation relevant to fire safety in buildings because they define the fundamental requirements of fire safety in buildings. In the context of quality assurance, they provide guidelines for the performance requirements of fire safety equipment and systems by referring to relevant codes of practice and British standards. The fire resistance test specified in the *Building Regulations* is regarded as a traditional way of ensuring quality control in the fire protection industry.

As a promoter of quality assurance, the government has encouraged independent certification schemes, developed a national accreditation system, and launched a quality awareness campaign—the 1983 National Quality Campaign.[6] These efforts resulted in the development of various quality assurance schemes by related quality certification bodies such as the Loss Prevention Certification Board (LPCB) and the British Standards Institution (BSI).

The government also exercises its influence on quality assurance through its public purchasing plans. The 1982 white paper pointed out that public purchasers can play an important role in improving the competitiveness of their suppliers by relating their purchasing requirements to national or international standards and by making great use of independent quality certification. The Property Services Agency (PSA), one of the largest government agents in the construction industry, made a great deal of progress in implementing such a policy.

Insurers

Because their principle objective is to protect property, insurers play a significant role in the fire protection industry and are involved in a wide range of activities that relate to fire safety in buildings. The quality of the fire protection equipment and systems in buildings has been one of their major concerns. Their activities in quality assurance fall mainly into three categories: standards making, quality certification, and procurement control.

Backed by insurers, the Loss Prevention Council (LPC) publishes a comprehensive series of performance standards, known as the Loss Prevention Standards (LPS), that define the insurer's requirements for fire safety equipment and systems. While some of these standards are identical to the British standards, others are supplemental. These standards are recognized and used widely in the design, specification, manufacture, and installation of fire safety equipment and systems. Examples of these standards include the LPC Rules for Automatic Sprinkler Installations, the LPC Rules for Automatic Fire Detection and Alarm Installations for the Protection of Property, and so on.

The Loss Prevention Certification Board (LPCB), an authoritative quality certification body in the field of fire safety engineering, is a constituent member of the Loss Prevention Council. The link between the LPCB and insurers enables the insurers to influence the LPCB's certification criteria and policy, while the insurer's recognition of the LPCB's certification mark strengthens the LPCB's authoritative position.

Fire safety designers often seek an insurer's involvement in the design and specification stage of the building. This early involvement enables insurers to influence and control the design of the fire safety systems and to specificy which fire protection products are to be used. Therefore, insurers are able to contribute to the quality of design and to advise or require their clients to procure quality products and services.

Quality Certification Bodies

Quality assurance provides the evidence needed to establish the public's confidence in the quality of products and services. Certification bodies are the medium through which quality assurance is accomplished, for quality certification marks are regarded as evidence of quality in the marketplace.

The major role of the certification bodies is to ensure that certified companies have achieved and maintain satisfactory levels of quality management conforming to the standards. They do this by performing quality audits and inspections.

Because the market recognizes the authority of certification marks, certification bodies possess the power to influence the status of quality assurance in related industries. Research finds that changes in quality certification schemes can have a powerful influence on quality assurance practices in an industry,[1] as is evidenced by the impact the LPCB's quality schemes have had in recent years.

The LPCB has announced its plan to replace its traditional quality approval schemes with new quality certification schemes, which require that the certified companies possess quality systems in accordance with BS5750/ISO9000.[7,8] This new requirement has been a driving force in hastening the adoption by fire safety engineering firms of the BS5750/ISO9000 quality systems. In interviews with the authors, some quality managers suggested that their companies would not have established these quality systems had they not been mandated by the LPCB's new certification schemes.

Building Authorities

In the context of fire safety in buildings, building authorities work as quality controllers. The Building Act 1984[9] states that it is the building authorities' responsibility to ensure that the *Building Regulations* have been followed throughout the design and construction of a new building. The building authorities must also approve the design of a new building before construction can begin.

One of the building authorities' tasks is to ensure that the fire safety design of a building conforms to the Regulations. The building authorities may also require that the performance of a particular system or piece of fire safety equipment conform to the relevant British standard. And when a building is commissioned, representatives of the building authorities act as quality inspectors to ensure that the completed building complies with its approved design and specification. This enables the authorities to control the quality of fire safety design in general.

The new 1991 *Building Regulations*[10] promote the use of the engineering approach to fire safety design, which allows more flexibility in the design of fire protection systems. However, it is important to ensure that alternative engineering methods can achieve adequate levels of fire safety in the buildings, as well. A key issue here is the quality of the fire safety design and the quality of the engineering facilities that are used.

Fire Authorities

The Fire Precautions Act 1971 and relevant fire precautions orders allow the fire authorities to carry out compulsory fire certification for certain types of buildings. And the Fire Safety and Safety of Places of Sport Act 1987[11] grants the fire authorities the power to serve prohibition notices without reference to a court. Such notices prohibit the notified buildings from being used for certain types of occupancies.

The purpose of fire certification is to ensure that the designated premises have adequate means of escape and that they conform to other, related fire safety requirements. Although fire certification is primarily concerned with the availability and adequacy of various fire safety measures, it is obvious that the certified facilities must meet a certain general level of quality and reliability if these fire safety measures are to be available at all.

Fire authorities do not commonly require that the fire safety equipment and systems installed in buildings be certified. However, some fire certificates may refer the fire safety equipment and systems to the relevant British standard. For example, a smoke detection system may have "to comply with BS5839 Part 1 at the L2 standard."[12] In cases in which the fire inspectors are not confident about the quality of the fire equipment, they may ask for test reports or other evidence of quality assurance. It is expected that quality assurance of fire safety equipment and systems will become a more important fire certification requirement in the future.

Unlike the building authorities, the fire authorities have no legal role in the design and construction stages of a building because the building is not certified until it is occupied. However, building owners and contractors may consider it necessary to seek advice on the fire safety design from the fire authorities, who are thus able to contribute to the quality of fire safety design, as are the insurers and the building authorities.

Trade and Professional Bodies

The influence a trade association can have on the development of quality assurance can be seen in the example of the British Fire Protection Systems Association (BFPSA). The BFPSA states that one of its principle objectives is, "To uphold and enhance the professional status of the fire protection industry by encouraging the adoption of improved standards for personnel training, systems design, equipment quality, and after-sales service."[13]

As a influential trade association, the BFPSA has been actively involved in developing standards and codes of practice for fire protection systems and equipment since its early days. Representatives of the BFPSA are invited to join the relevant working groups of the British Standards Institute and the International Standards Organization.[14]

The BFPSA has also been involved in quality certification recently, working with the Loss Prevention Certification Board to develop and launch the LPS 1014 Quality Assurance Scheme for the Certification of Fire Detection and Alarm Companies. In addition, it works closely with the British Approvals for Fire Equipment (BAFE) to promote third-party quality certification.

The BFPSA also works as a liaison between the regulatory bodies and industry. It is a founding member of the U.K. Sectoral Committee Operating for Fire and Security (SCOFS), whose objective is to represent the collective views of manufacturers, users, and third parties on the perceived market demand for conformity assessment in fire protection and security products. Its links with the regulatory bodies allow it to inform them of industry concerns and to inform its member companies of any changes or potential changes in legislation that may affect the industry.

Other trade and professional bodies, such as the British Automatic Sprinkler Association, the Fire Extinguishing Trades Association, and the Institution of Fire Engineers, play roles similar to that of the BFPSA by promoting communication among industry companies, professionals, their clients, and the regulatory bodies. The demand for quality is a prominent message. Professional bodies such as the Institution of Fire Engineers and the Fire Protection Association also work to improve the competence of professionals through education and training. Professional competence should always be a part of the framework of industry quality assurance schemes, for the competence of the staff is a prerequisite of quality.

Further Discussion

In summary, the quality of fire safety equipment and systems in buildings is not only the concern of users and suppliers, but the concern of a number of social groups and organizations, as well. Such groups and organizations provide a framework for the macro quality assurance system and contribute to the development of quality practice in various ways. Having discussed the functions of the major components of the system, the authors would like to highlight several other points.

First, the fire safety engineering industry's client group, which consists of building clients, building contrators, building services contractors, and other purchasers of the fire safety equipment and systems, is an important component of the system. In fact, clients play an essential role in the development of quality systems.[1] Their influence on the quality practice of a fire safety engineering firm is straightforward: they usually specify quality system certificates as a condition for tender.

Second, the macro quality assurance system's objective is to ensure that the quality of fire safety engineering in buildings is satisfactory. Because the key to achieving this objective is ensuring quality assurance in fire safety engineering firms, the macro quality assurance system must promote quality assurance in such firms.

In recent years, quality assurance has focused on the development of quality certification and the use of the BS5750/ISO9000 quality system, which provides an excellent framework for the micro quality systems that operate in individual companies. However, it can be argued that the introduction of such a quality system does not always lead to the development of sound quality management practice. Many companies are now working toward a total-quality approach that requires changes in attitudes toward quality and changes in company culture. It is essential that the macro quality assurance system build a quality climate in industry that will encourage and support the development of the total-quality approach.

With the development of quality certification schemes, the problem of multiple testing and assessment from different certification bodies has begun to worry some companies. Certification bodies, as well as organizations such as the BAFE and the BFPSA, have recently made a considerable effort to harmonize these certification and approvals activities. Because of industry tradition and the complicated structure of the fire protection industry, however, this problem is likely to remain with us for a while.

In a building project, the various aspects of fire safety engineering are usually divided into a series of separate work packages which are then contracted to various firms at various stages. Such a fragmented procurement process requires a systematic approach to ensure the quality of the project.[15]

The macro quality assurance system is an important part of the overall approach to total quality because it encourages the development of an essential environment in individual companies and individual projects for quality assurance. The construction industry has recognized the need for quality, but it is meaningful to examine the matter of quality assurance in a broader context. The macro quality assurance system of the fire protection industry should fit into the total system of the whole construction industry.

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